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ORDINARY MEETING.

14 April, 1942.

PROFESSOR CHARLES EDWARD INGLIS, O.B.E., M.A., LL.D., F.R.S., President, in the Chair.

On the motion of the President, it was resolved :—

"That the President and Council and the Members of The Institution deeply regret the death of Sir William Henry Bragg, O.M., K.B.E., F.R.S., who was elected an Honorary Member of The Institution in November 1936 in recognition of his eminence as a scientist and as President of the Royal Society and Director of the Royal Institution of Great Britain; and that an expression of sincere sympathy be conveyed to the members of his family."

The Council reported that they had recently transferred to the class of

Members.

Albert Frank Allen.
Samuel Henry Windrum Middleton, B.A., B.A.I. (*Dublin*).
Frederick Gaston Penny.

And had admitted as

Students.

John Bryce Wesley Abell.
Peter Philip Arnold.
William Oackley Bishop.
Keith Richard Bowman.
Frank Brocklehurst.
Arthur Burrell.
Arthur Dudley Carvin.
Peter Wilford Dunn.
John William Evans.
Ian MacInnes Gardner.
Alan Graeme Gibb.
Georgios Costa Hajicosta.
William Roy Hall.
Samuel Clifford Hardy.
Kenneth Cedric Harland.
Henry Stephen Lyn Harris, B.A. (*Cantab.*).
Thomas Alan Heatley.
Arnold William Hendry.
Maxwell Hubert Shaw Holgate.
Donald Jones.
Owen Jeffreys Jones.

Trevor Charles Greenford Jones.
Desmond Joseph Kealey.
Peter Douglas Knowles.
Donald Lindsay.
John Linning.
Ronald Vernon Mathews.
Maurice Douglas Pearson.
James Ian Morton Pitchford.
Gordon Johnson Polson.
Alfred Glenton Preston.
Ernest Ramsay.
Donald George Combe Riches.
John Elias Roberts.
Peter Walter Rowe.
Michael John Chambers Smith.
Charles Bolton Statters.
Derek Vivian Stone.
Charles McLeod Strachan.
Edward Norman Thomas.
William Ian Thomson.
David Lewis Marchant Upchurch.
John Douglas Watts.
Charles Henry Webb.
Alan Halsall Williams.
Basil Patrick Williams.
Elwyn Lewis Williams.
Olgierd Cecil Zienkiewicz.

The Scrutineers reported that the following had been duly elected as

Associate Members.

Robert George Smeed Avery, B.Sc. (Eng.) (*Lond.*).
Edward Mervyn Evans, B.Sc. (*Wales*), Stud. Inst. C.E.
James McLachlan Fairlie.
Henry Gill French, Stud. Inst. C.E.
James Caldwell Gray, B.Sc. (*Glas.*).
Reginald Brian Hardcastle, B.Sc. (Eng.) (*Lond.*), Stud. Inst. C.E.
Arthur Vernon Robert Hooker.
Raymond William Horner, B.Sc. (Eng.) Stud. Inst. C.E.
James Howard George Johns, B.Sc. (Eng.) (*Lond.*).
Vishwa Nath Khanna, B.Sc. (Eng.) (*Lond.*).
Alexander John Knight, B.Sc. (Eng.) (*Lond.*), Stud. Inst. C.E.
Sidney Charles Moore, B.Sc. (Eng.) (*Lond.*).
Geoffrey Whitemore Pickin, B.Sc. (Eng.) (*Lond.*), Stud. Inst. C.E.
Benjamin Charles Graham Stevens, B.A. (*Cantab.*), Stud. Inst. C.E.
Clifford Edward Oldfield Walker, Stud. Inst. C.E.
Henry Cecil Walker, B.Sc. (*Queens*), Stud. Inst. C.E.
Colin Verdin Whitehead, B.Sc. Tech. (*Manchester*), Stud. Inst. C.E.

The following Paper was submitted for discussion, and, on the motion of the President, the thanks of The Institution were accorded to the Author.

Paper No. 5317.

"Post-War Planning and Reconstruction." †

By Herbert John Baptista Manzoni, C.B.E., M. Inst. C.E.

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Introduction.

Great disasters and major wars frequently have resulted in considerable improvement in the physical standards of the people whose homes and properties have suffered damage.

Great Britain has been singularly free from major disaster over a long period of time. The great fire of London in 1666 is probably the most recent example of wholesale destruction of property at all comparable with the damage caused in the past two years by enemy action in many cities and towns of Great Britain.

The facts are different in many countries on the Continent of Europe. France, Belgium, and some of the mid-European States suffered very heavy physical damage during the last great war and some of those which escaped physical damage, for example, Germany and Austria, sustained, as ingredients of defeat, so pronounced financial and industrial disaster as to produce psychological reaction very similar in direction of effort and in result.

The rebuilding and new building which has been effected in some of those countries during the past twenty years surpasses in scale and variety anything which has been achieved here at home with the single

† Correspondence on this Paper can be received until the 15th August 1942, and will be published in the Institution Journal for October 1942.—Sec. Inst. C.E.

exception in scale of the production in the British Isles of four million houses. Unfortunately that single exception was very limited in aim; moreover it lacked to a great extent the urgency of a national demand arising from an upheaval in the normal lives of the people. It is interesting that the unbalanced nature of the achievement became evident alike to informed opinion and to the general public, and gradually it was creating the need and the conditions for a drastic change of national policy. The growth of monotonous dormitory suburbs, the consequent spread of urban areas, and the uncontrolled flow of industry to the expanding centres of population gave rise to serious apprehension and stimulated successive Acts of Parliament and investigations. Examples of the former were the Town and Country Planning Act of 1932 and the redevelopment sections of the Housing Act of 1936. An example of the latter is the Royal Commission on the Distribution of the Industrial Population, whose Report was presented so recently as 1939.

It is interesting also that the basic cause for the redevelopment legislation (slum clearance and overcrowding) was a much more comprehensive reason for reconstruction than the necessity for repair and rebuilding of properties damaged in air raids; it still remains the more urgent reason for replanning and rebuilding, but it lacks appeal to the popular imagination.

The opportunities which have arisen from damage by enemy action, however, are much wider in their possibilities; they are wider in extent than the actual damage itself; they have the reinforcement of the upheaval of industrial and domestic life and already they are productive of results far reaching and revolutionary in character.

National planning as a basis for development and redevelopment already is accepted as Government policy. Control of the use of land has been anticipated by the setting up of the Uthwatt Committee. Nationalization of land is by no means an improbability, and indeed the precedent already exists in pre-war legislation whereby nationalization of mineral rights was effected.

The special committee under Lord Justice Scott is considering the use and development of rural land in all its aspects, and certain Ministers of the Crown are charged with the consideration of social and economic as well as physical reconstruction and reorganization on a nation-wide scale.

Much more is necessary, and there is little doubt that further investigations will be undertaken by the Government as opportunity occurs. A considerable range of investigation already is in progress unofficially and with official encouragement. Financial institutions and societies are investigating the possibilities of economic reorganization without which wholesale reconstruction is extremely difficult. The reorganization of local government as an essential part of the national administrative machine is being considered, and public utility undertakings dealing with water-supply, the production of gas and electricity, and the management

of transport have their own central and local committees for the consideration of post-war planning problems.

At this early stage in the development of an organization for planning and reconstruction on a national scale it is perhaps impossible to forecast the precise form which eventually will be achieved. National experience will play an important part, national characteristics will shape the structure as it grows, and the widespread nature of the Empire will doubtless be reflected in the policy which will emerge.

It would not be true to assert that Great Britain is backward in its consideration of planning; the subject has had legislative form for the past fifty years, and a definite recognition since the first Town Planning Act of 1909.

It is doubtful whether an urgent need for national planning was apparent prior to 1918. The country was powerful and prosperous, the standard of living of the people was high and rapidly improving, communications were adequate, the development of canals and railways was, in fact, a pioneer achievement on a national scale, and the necessity for a system of national highways such as the French *routes militaires* or the German *Autobahnen* did not exist.

It is quite true, however, that other nations, owing to one or other necessity or influence, have advanced beyond Great Britain in planning matters and, by force of circumstances, in large-scale reconstruction.

Planning and Reconstruction in Europe and America.

France and Belgium, influenced largely by the destruction occasioned during the war of 1914–1918, have concentrated upon wholesale rebuilding of damaged towns, the work being carried out by local authorities aided financially from State funds.

Italy constructed the first system of motor roads in Europe and undertook a programme of rebuilding certain towns on a very ambitious scale. It is difficult to trace the actual cause of these activities. They probably arose more from the awakened activity of the nation during the early fascist regime than from any economic or industrial need for reconstruction.

The first country in Europe to adopt a policy of national planning was Rumania which, in 1929, adopted a system of national reorganization based upon industry, agriculture, power resources, and cultural development.

Bulgaria has followed part of the way by preparing individual schemes for national and regional development of certain resources, including agriculture and industry, but not all of them have legal recognition.

Neither of these two countries seems to have implemented its plans by any comprehensive programme of reconstruction.

In Germany the road-building projects which have become widely

known throughout the world probably originated in the need to find work for many millions of unemployed consequent upon economic depression. The military significance of this work was probably secondary, although there is no doubt that the national road system, in condition as well as in design, was formerly deplorable. The economic collapse of the country was a major disaster, but it resulted in a reorganization of financial policy whereby the values of labour and local materials were related to production, and this undoubtedly facilitated the very comprehensive schemes of reconstruction and new building undertaken in Berlin, Munich, Nuremberg, and many other towns. The direction in this case was national rather than local, and much of it was also political; and in 1933 this resulted in a very comprehensive national, regional, and local organization for planning and reconstruction.

The United States of America have experimented with planning and reconstruction projects. They have built a few new towns on the satellite pattern and have carried on a considerable amount of suburban development under modern town-planning principles. The underlying reason for the reconstruction in the larger American cities has been traffic requirements, and there has been a very interesting development of low-rental housing projects within the towns as an outlet for investment money held by Insurance Companies and Banks: practically the whole of this work seems to have been local in character, or in some cases State-controlled.

By far the most interesting and also the most progressive development of planning and reconstruction in the modern world has occurred during recent years in the U.S.S.R., as a direct result of the policy of industrialization of that country since the last great war. Twenty-four years ago Russia was much more backward in town-planning matters than we were in Great Britain, but to-day the work of the Russians in this field is far ahead of any other comparable achievement in the world, and they have twenty years of solid experience in hand to help with future plans. For example, one new town was built as part of their programme according to a town-planning theory popularly expounded in Great Britain over the past half-century. The inhabitants discovered defects in the scheme and as a result the town was largely remodelled and rebuilt.

Planning and reconstruction in the U.S.S.R. had the easiest possible basis for progress—the complete nationalization of all land, natural resources, and buildings—and the reconstruction programme was commenced in 1920 on the basis of production of heavy industry. In the succeeding years an economic plan for the whole country was evolved, industrial development was planned on a national scale, a complete survey of national requirements and national resources and of their development was made, and in 1928, when the first five-year plan was launched, it was possible to lay down the lines of development, the future size, and the character of many large and small towns and many rural areas.

With these fundamental factors established, with land, mineral

resources, and buildings owned nationally, and with an economic system related to basic values, progress was very rapid, the smaller portion of the national scheme including, in 1928, plans for the rebuilding of ninety-six towns having populations exceeding 50,000. By 1940 the number had increased to 225, of which 145 had been completed.

In the early days of this programme technicians were very scarce and help was welcomed from professional men of other countries; but subsequently a national organization was built up based upon a State Planning Commission, which laid down a programme of economic development. The portion of this programme involving physical building is considered by the local authority concerned and, after agreement, is sent to a central planning bureau which prepares the planning schemes for all towns and inhabited areas in the particular Republic or State. The individual schemes again are criticized and agreed by the local authorities, who then become responsible for the carrying out of the building work.

It is interesting to consider the organization of these central planning bureaux. Immediately before the present war the bureau which operated for the Ukraine had about 400 employees, including many women. Sixty of them were architects, seventy were engineers, and forty-five were economists, geologists, meteorologists, agriculturists, and other specialists. Moreover, the distinction between engineers and architects does not exist in Russia as it does in Great Britain. There are specialists in planning, in scientific construction, and in the treatment of civil buildings, but these specializations are allied parts of a single profession.

Basic Principles.

Post-war reconstruction in Great Britain, if it is to mean anything beyond the repair and rebuilding of structures damaged by enemy action, must become a comprehensive undertaking organized on a national scale. It will be the chief occupation of the whole country for the next half-century or more, and is bound to result in an upheaval of practically all public and private interests. The ultimate results and the rate of progress will depend inevitably upon the early settlement of certain basic fundamental principles, and it is encouraging to find that these matters are being examined at the present time.

The principal items concerning which decisions are required as a basis upon which the work of an organization for reconstruction can proceed are:—

(1) industrial expansion and distribution;
(2) agricultural policy;
(3) land tenure and the ownership of buildings;
(4) finance.

These subjects are not within the scope of town and country planning,

but physical planning on a national scale is completely dependent upon them.

(1) *Industry.*—The industrial expansion and prosperity of Great Britain during the past century was not planned nationally. It was the result of private endeavour and initiative and was largely individualistic; but this was possible only because Great Britain was the first in the field and for many years held the lead. These conditions have passed and are not likely to recur. In the future, industrial prosperity will depend either upon competition with other highly-organized nations or upon international allocation and agreement. A decision on these matters will settle the type of industry which will decline or expand, and the size and type of ports and internal communications will depend upon it, as well as the growth of centres dependent upon particular manufacturing processes.

Distribution within the country is very important. Many industries are geographical and cannot be moved—mining, quarrying, and shipbuilding are in this category; others are more or less independent of position, provided adequate communications are established. Some towns have achieved a distribution of industry which is capable of absorbing labour during periods of slump and depression. In Birmingham, for example, the unemployment figure has seldom risen above 4 per cent. of the total population. Lancashire and South Wales are examples of districts where excessive unemployment is caused by the concentrated nature of single industries.

Extensive research is necessary into the complementary character of industries; for example, industries which thrive whilst others are depressed, and those whose processes are allied or sufficiently similar to allow of interchange of labour. Distribution, therefore, should be planned accordingly.

It may be difficult—perhaps impossible—to give a complete answer to these queries until after the war, but it should be quite practicable to give a general lead upon which to build a planning organization.

(2) *Agriculture.*—A soil survey of Great Britain is in progress at the present time; in fact it is almost complete, and it will soon be possible to decide which portions of the land are best suited to particular agricultural purposes, market gardening, arable, or grazing; but it is equally important to know the extent to which agriculture is to be exploited. It is a matter of mathematics to estimate the productivity of the available land, but quite another matter to decide the policy of exploitation. In the past 50 years local agriculture has declined in compliance with a deliberate policy of importation from the Dominions and foreign countries; but those sources of supply are becoming more highly industrialized and therefore less subject to barter.

If agriculture is to be pursued in Great Britain to the nearest possible approach to self-sufficiency, then new urban development must be kept away from the better agricultural soils even if particular sites are highly

desirable from every other point of view. Between 1918 and 1940 more than 500,000 acres of the most fertile agricultural land was built upon. The establishment of agricultural industries, preserving, canning, etc., has a direct bearing upon these decisions.

(3) *Land Tenure.*—It can hardly be denied that the best possible condition for ordered planning and reconstruction is State ownership of land and buildings. For many reasons this may be impracticable in Great Britain, and it may be necessary to devise another form of control; but there must be control if schemes are to be complete and ordered and if there is to be any attempt to pursue reconstruction on a measurable time-basis. The control of land use must be definite and not subject to argument and litigation. The planning authority should be in a position to state exactly what may or may not be done with any particular site or sites, and the control must extend to every square yard of land in the country. The planning authority, moreover, must be in a position to require its decisions to be implemented according to a definite time-schedule.

(4) *Finance.*—Prior to the present war the original cost of almost any building project was represented, as to about 50 per cent., by the value of labour and materials, and as to the remainder, by interest on capital. In the case of housing, this meant that half the rental was on account of interest, and in the case of commercial enterprises the price of the product was similarly inflated. The anomaly is fundamental in our financial system and is purely artificial. The reconstruction of the cities and towns of Great Britain is so vast a project that it is almost impossible to undertake it without a revision of the financial system towards truer values.

Planning Organization: National Planning.

The determination of a sound national policy in respect of these four fundamental problems will probably call for the setting up of some form of Commission or Commissions armed with the necessary powers to require the various Ministries and Government departments concerned to prepare workable schemes for the matters within their respective provinces. At the present time the Ministries affected are the Board of Trade, the Ministry of Agriculture, and the Treasury.

On the assumption that solutions to these problems will be found, it is possible to envisage an organization suitable to the experience and traditions of the country for the preparation of co-ordinated schemes of planning and reconstruction and the eventual carrying out of the work.

A scheme on the model of Dictator States where arbitrary decisions, however efficiently implemented, are imposed upon the public, would not be acceptable; nor, in the Author's opinion, would a scheme similar to that which has been successful in the U.S.S.R., where highly-educated and informed opinion had, of necessity, to be collected, because of its

scarcity, into a single group or a few groups to prepare and administe schemes of reconstruction for very large areas.

For many years local initiative in Great Britain has been of a higl order and local authorities have attracted to their service, in official an unofficial capacities, men of good business and professional qualifications It is true that during very recent years the intensification of an onerou control from remote Government departments has to some extent dis couraged many able people from participating in local management, an the introduction of politics has had a similar effect; but the nucleu remains and the conditions can soon be remedied. Local interests ar well suited to control reconstruction in Great Britain if sound and co ordinated guidance on a national scale is provided, together with prope means for accomplishment.

National guidance would probably be best achieved by the setting u of a Ministry of Planning, whose work would be based upon the principle decided by the Commission referred to earlier, and whose functions coul be expressed under a few major headings, such as :—

(1) the preparation of a national skeleton plan ;
(2) the determination of national standards ;
(3) research ;
(4) the approval, co-ordination, and enforcement of all detail plans

These tasks should be well within the compass of a reasonable and well proportioned Government department and would not require a vas departmental machine which, by reason of its size, would be cumbrou and slow in action.

(1) *The National Skeleton Plan.*—A national plan should be base upon the very broadest interpretation of the main lines of policy con cerning industry and agriculture. Its chief features should be communica tions and zoning ; but whereas the system of communications would bes be considered and worked out in detail by the central Ministry, the zonin proposals could be in outline only, the details remaining to be settled b the authorities responsible for detail planning.

Communications should be interpreted in the widest possible sens and should include roads, railways, canal and river transport, and coasta and air-borne traffic ; but the skeleton plan need take notice only of mai traffic flow between districts or centres of population. For this purpos it will be advisable to divide the country into a number of regions— necessity which becomes more apparent when detail planning is considered

The factors which should govern the boundaries of these regions ar numerous and complex and it is impossible completely to satisfy all o them. In the main, however, the regions should be such that a balanc of physical factors is contained within a single unit of control, and th areas should be large enough to allow of balanced planning as betwee urban and rural development, but not so large as to lose the advantage

of local cohesion. If the chief centre of urban development is considered as a nucleus, then the region should represent the sphere of influence of that nucleus.

National zoning would include the reservation of national parks, the preservation of places of scenic beauty, moorlands, mountains, the sea-shore, and large-scale recreational areas of a national character. It would include also proportional zoning within the regions based upon the industrial and agricultural policy adopted for the country. The actual siting of industry and rural development is a matter for regional and local determination, but the proportions of different types of industry and of agriculture within the regions is a matter for national determination.

As an example of the co-ordination of these functions, it might be decided that the development of international trade would require the establishment of a new port on the east coast; this would be considered in relation to existing port facilities and would be within one of the regional areas. The region would then be considered as a whole and the influence of the new development would be related to the trade and industry already established, the aim being to provide a balance which would not be subject to periodic depression or boom. Communications with other parts of the country could then be planned, the volume and type of traffic would decide the size and direction of roads and railways, and the excess or deficiency of industry of any particular types would determine the policy of decentralization or concentration of the region in relation to other regions of the country.

(2) *National Standards* and (3) *Research.*—Already codes of standards are in existence concerning certain physical matters—building by-laws for example, which represent minimum conditions of building and sanitation. The overcrowding standards of the Housing Acts, the standards for street lighting issued by the Ministry of Transport, and the requirements of the Public Health Acts, are all national standards. There is also at the present time an effort by the Ministry of Works and Buildings to standardize codes of practice.

Most of the existing standards require revision and co-ordination and there is a need for a considerable extension of this form of guidance to cover, *inter alia,* the proportions of open space for recreational purposes, atmospheric purity, heating and lighting of the different types of buildings, maximum area of urban development in relation to industrial use, densities of development for residence and manufacturing use, green belt reservation, and the use of agricultural land for market gardening, arable, and grazing.

The fixing of standards and the research which should precede it are matters for national consideration by a Planning Ministry, but it is important that a certain flexibility should be allowed to accord with local conditions which have a considerable influence on detail.

(4) *Approval of Detail Plans.*—This function has been exercised in the

past by the Ministry of Health, and it should pass, with other plannin functions, to a Planning Ministry. There is a danger that any nationa body would attempt to exercise too rigid a control over detail work, an although it is necessary to ensure that detail plans for reconstruction an future development are properly co-ordinated, the plans themselves shoul be a matter for local preparation; they should be prepared by loca persons having an intimate knowledge of local factors—preferably b persons whose life and circumstances are parts of the plan itself. Th detail plan should express the wishes and requirements of the populatio of the district so far as these are consistent with national policy, and fo this reason a remote Ministry or persons under the control of such a authority should not attempt to plan in detail except such features of national character as national communications. The Planning Ministr must, however, exercise the functions of co-ordination and ultimat approval in order to ensure that national factors and standards ar properly complied with.

It is probable that certain other projects will be developed on national basis, in which case they will fall within the province of a Ministr of Planning. The generation and distribution of electricity is an example and water-supply is possibly another. Such projects are highly specialize in character, but nevertheless they are subordinate to the programme o planning and reconstruction, of which they form an essential part. I fact, physical planning of land use is so comprehensive and fundamentall important that it ought to take precedence of everything except matter of major national policy.

Detail Planning Units.

For many years the function of detail planning has been exercised b local authorities, and since 1932 all local authorities other than count councils have been required by statute to prepare planning schemes fo their areas. The smaller urban and rural districts, in many instances have combined with county or sub-county areas to prepare schemes on scale more adequate than would be possible within their individua boundaries. Some of the larger boroughs also have attempted co-ordina tion, through Joint Committees, with surrounding rural districts; but i many cases these efforts have been comparatively unproductive of con spicuous results because of the conflict of interests involved. It may b in the interests of a town that the surrounding rural districts should b sterilized against urban development; but such a restriction means los of potential ratable value and agreement becomes difficult, if no impossible.

The obvious unit for detail planning is one in which the proportions o urban and rural land are balanced according to the requirements of th population. This balance cannot apply in all cases to the complete agri

cultural needs of the people, because in the case of a very large town the area of rural land would be most extensive, but it certainly should apply to rural land used for market gardening and balanced amenity.

Other desirable criteria are areas of water-supply, natural drainage-areas, and areas bounded by major physical features. It is seldom, however, that these factors can be achieved without undue extension beyond a size suitable for local unity.

It is certain that the planning units which have operated in the past have not been suitable. The county borough is completely unbalanced in so far as it seldom has much, if any, rural land within its boundary, whilst the county (without the county boroughs), although a much better unit of size, is lacking in the advantage of intensive urban development with its consequent ratable value. This lack of suitability for planning purposes of existing local authorities' areas is shown by the efforts at collaboration by means of Joint Committees which have been a feature of the past twenty years.

The desirable area for detail planning would also be more suitable for many other purposes than present local authorities' areas; for example, higher education, the university, health and hospital services, transport, gas and water distribution, and sewerage and sewage-disposal. Many of these services have developed on regional lines during recent years for the obvious reason that the local authorities' boundaries are too restrictive for their adequate economic and efficient expansion.

To cover this expansion a mass of permissive legislation has accumulated in the form of private Acts of Parliament, each varying from the others in detail and sometimes in principle.

There would appear to be two direct solutions of these difficulties, namely :—

(1) the revision of local authorities' boundaries on a regional basis;
(2) compulsory collaboration of existing local authorities within definite regions.

The former system has the advantage of simplicity, but if applied immediately it would involve considerable interference with local vested interest as represented by rural and parish councils. It may prove eventually, however, to be the most effective, although it may suffer from local opposition and antagonism for some time.

Compulsory collaboration of existing authorities may be more readily acceptable, and would retain the advantage of local knowledge and interest. On the other hand, there would be more clash of opinion—often uninformed—in major planning considerations, and consequently more difficulty would be experienced in reaching agreement on sound lines.

Regional Collaboration.

The object of regional collaboration is to ensure that the land within the regional boundaries is laid out in the most convenient manner to provide for its industrial, residential, recreational, and agricultural use in accordance with the national plan and national standards. Artificial boundaries of existing local authorities should be completely ignored in the process.

Within the industrial proportions settled by a Planning Ministry, new industries should be established wherever regional facilities are best suited to their needs. Existing industries and centres of population should be supplemented or decentralized without regard to the effect upon purely local rates and property values. Existing towns which have grown too large for the provision of adequate amenities for the people should be reduced in density and area by a process of "thinning-out" and a complementary establishment of new industrial centres with residential and social environment.

This establishment of new towns may take the form of satellite communities of small size dependent upon established towns or cities for certain communal services, in which case distance and communications are vital, or it may require the building of larger self-contained units complete in themselves, the population of which might be planned as high as a quarter of a million. A further alternative, dependent upon local circumstances, is the expansion of an existing small community by transfer from a large one.

In certain cases, classes of industry may have to be transferred from one region to another in order to reduce over-weighted proportions or to make up deficiencies. The principles governing these decisions must be settled nationally, but the details of arrangement are regional matters.

Secondary communications also are regional matters; for example the layout of main roads (other than those included in the national plan) connecting the various towns and villages in a regional area; the establishment of green-belt lands restricted to market gardening or recreational use, and the consequent limitation of building land; and the scheduling or zoning of land for agricultural development or agricultural industry. In addition there are many social and health matters which require regional planning and control, some of which have been mentioned earlier.

Under a system of regional collaboration the final stages of planning could well be carried out by local authorities within their present boundaries, provided always that the authorities are large enough and have sufficient scope and importance to enable them to employ qualified officials or consultants to ensure that the planning is sound. These final stages consist of the zoning and detail layout of residential estates, industrial districts, civic centres, parks and open spaces, main and subsidiary roads and paths, and services of all kinds.

Existing county, county borough, and district authorities have performed this work for many years, and have accumulated considerable knowledge and experience of the subject.

Reconstruction and New Construction.

The two major defects of town and country planning in the past are that it has been delegated individually to a large number of authorities with little, if any, co-ordinated policy, and that there has been no balanced construction programme to implement the plans. In view of these deficiencies the results obtained can be considered extremely good, but they cannot compare with the results which should accrue from an organized and properly co-ordinated effort implemented by a construction programme on a fixed time-basis.

The two major planned construction projects of a national character in Great Britain during the present century, excepting those incidental to the two wars, are the housing programme and the slum clearance programme. The grid scheme of generation and supply of electricity might be included also but, unfortunately, it was not co-ordinated with town and country planning and may prove to be out of alignment with it.

Reconstruction and new construction have proceeded (the latter at a very rapid pace) during this period, and to some extent they have been controlled by local planning requirements ; but apart from the requirements of local zoning there has been no policy of industrial distribution and little co-ordination of planning schemes other than legal alignment and detail standardization. Until the passing of the Trunk Roads Act in 1936, there was no control of national communications, and even that step has resulted only in the minor activity of repair and improvement of existing highways and the construction of a few by-pass roads.

Small schemes of reconstruction have been attempted locally in some towns, but the financial capacity and powers of the local authorities have been quite inadequate to carry them out in a proper manner.

It is to be hoped that a national organization of town and country planning will be implemented by the granting of adequate powers to planning authorities, together with the necessary labour, materials, and money to enable them to embark upon a definite programme of new construction and rebuilding on a reasonable time-basis. It is not by any means necessary that planning authorities should themselves undertake all, or even the major portion, of the building work to be done. Their activities need not extend to much more than they have attempted hitherto, namely, the provision of civic buildings, roads, services, and low-rental housing, but they should have power to require private building or rebuilding to proceed according to a time-programme, or in default to take over and order the work themselves. For this purpose it would be necessary to introduce a system of licensing the " lives " of existing buildings, the " life " in each

case being fixed according to the requirements or urgency of the corre-sponding part of the plan and also, as far as possible, according to th condition of the building.

Many parts of our towns and cities do not need rebuilding; othe parts need only local improvements; but in almost every urban are there are districts which should be completely cleared, replanned, and i some cases rebuilt. Some of these districts should be left as open space and converted into parks, whilst others should become residential c industrial; but reconstruction should be complete if it is to be effective and it should be possible to carry out a national programme on these line in about 50 years.

Redevelopment.

Redevelopment may include operations ranging from the replacemen of a single building, or a group of buildings, to the reconstruction of a com plete district half a square mile or more in extent. Single buildings c groups of buildings present problems which are familiar to engineers c architects and require little comment. Perhaps the most importan change likely to be met is that there will be an effort to ensure that th new structures comply with a definite standard of appearance in order t achieve aesthetic unity in a particular district.

The redevelopment of a large area of a built-up town is one of th most difficult problems likely to be encountered in post-war reconstructio Such a project is similar in many respects to the building of a new town but it is bound to be complicated by a number of existing features whic must be incorporated in the new plan, and the details have to be relate to the surrounding development.

The details of an actual redevelopment area of 267 acres upon whic work was in progress prior to the war are as follows:—

Nearly 11 miles of existing streets, mostly narrow and badly planned 6,800 individual dwellings, the density varying locally up to eighty to th acre; 5,400 of these dwellings classified as slums to be condemned; fiftee major industrial premises or factories, several of them comparativel recent in date; 105 minor factories, storage buildings, workshops, indu trial yards, laundries, etc.; 778 shops, many of them hucksters' premises seven schools; eighteen churches and chapels; fifty-one licensed premises with many miles of public service mains—water, gas, and electricity- including more than 1 mile of 42-inch trunk water-main, nearly all la under carriageways and consequently in the wrong places for good plannin

In this case the governing features are the presence of an arteri radial road which enters the district and divides into several seconda routes within it, a number of large industrial plants the removal of whi would not be in the interests of the area, and a number of very large trun service mains routed under existing streets (Figs. 1, Plate 1).

The traffic system of the town as a whole requires the retention of the radial road for the easy and rapid passage of vehicles through the district. Consequently a convenient line for its re-siting as one main highway was chosen and the road constitutes a construction member or backbone of the redevelopment plan. This main highway is not so necessary to the plan as it is to the areas beyond, and consequently it has been designed with a view to fast through traffic. Two carriageways separated by a central reservation are to be flanked with strips 50 feet in width, to be planted with shrubs and trees to form the nearest approach to a parkway which the rather limited space will allow. There are very few connexions to this highway from the land on either side, and whatever additional cross-connexion is necessary will be provided either by bridges or by tunnelled carriageways.

Buildings will have no direct connexion with the highway, but will front to special service roads beyond the tree belts, or will back on to the belts and front to an internal and separate system of roads forming part of the development on either side.

Industry is to be grouped into one main portion of the redevelopment area, with two small subsidiary groups, each of the sites being chosen according to the location of the major existing factories.

The whole of the road system is re-designed to serve the industrial, commercial, and residential areas, each road being suited to its particular purpose; in a few cases existing street lines are retained, especially where trunk mains occur and where the streets are not too badly placed to fit the new plan. In some places trunk mains will pass between buildings away from roads and probably will be under the sites of pedestrian ways.

It is anticipated that the owners of many of the small industrial concerns will wish to remain in the district, in which case it is intended that they shall be induced to share factory blocks or tenement factories located on the industrial sites and erected either by the local authority or by their owners in co-operation.

The re-design of roads has resulted in a saving of space of about 20 acres, and an equivalent area is devoted in the plan to open space to be used as parks and recreation grounds.

The whole of the houses in the district will be rebuilt, and it is found that by the adoption of varying types and heights ranging from two storeys to five or more it is possible to accommodate about 4,500 dwellings.

This scheme is one of five such areas in the town which have received consideration; and on the same basis of reduction of population it is obvious that about 10,000 families, or between 35,000 and 40,000 persons, must be displaced.

The town in question is one of those which already is inconveniently large, and the solution probably lies in the establishment of a satellite town about 5 or 6 miles outside the present boundaries.

New Towns.

The principles governing the design of a new town are somewha similar to those involved in redevelopment, but it is possible to effect much better distribution of land use, a lower density of building, and bette traffic arrangements.

The planning of the traffic arrangements is most important and, to b successful, it is necessary to appreciate that the system of almost ever town in Great Britain is, or until very recently was, completely unsuite to modern traffic.

With the exception of those on the coast, almost all towns in the pas developed quite naturally around road junctions, because the junctio was the meeting place of the highways, the halting place of long-distanc vehicles, and the place to change horses and take refreshment. It i remarkable that our main trunk roads lead directly into every town o their route, through the congested centres, and out again. The result i that a large amount of money has been spent in the maintenance an improvement of central town streets on account of traffic which has bee compelled to use them as traffic routes in the absence of direct or con venient alternatives.

In designing a new system, the highways should pass through ope country near to but not through the urban development (Figs. 2 and 3 Plate 1). The town should be an island approached and entered by wa of subsidiary roads branching off the highways and, if it is large enough it should have its own system of main communication roads consisting o radials connected by a series of ring roads. These roads should not b fronted by buildings, but should be designed as parkways, the building being erected in the blocks or sectors between the roads. Each buildin group should have its own system of residential or commercial street connecting with the main road system at convenient but not too frequen intervals.

Railways also should pass into the town through parkways, or else i tunnels under main roads.

Services.

The opportunity occurs in the building of new towns, and also in th major redevelopment of old ones, to introduce many of the improvement which are known to be desirable in the provision of normal services, an it is possible also to consider the introduction of new services. Th services provided to a modern community are numerous, and range fro protection against criminals to the delivery of newspapers. All of the have their place in the comprehensive conception of planning, but thos which most affect the work of the engineer are refuse- and sewage-dispos and the supply of gas, water, and electricity.

Public transport has to be considered in the planning of space use and roads, as also the buildings required by police, health services, fire-fighting organizations, education committees, etc.; but every building involves the provision of the disposal and supply services mentioned.

The production of gas and electricity, the supply and storage of water, and the disposal of sewage and refuse have each been the subject of advanced scientific research during recent years, and doubtless improvements in these services will be continued by this means; but distribution methods have been subject to the urban conditions of the towns and have remained practically stationary. A simple system of generation and disposal on the site seems to be impracticable (although if possible it would be ideal), and therefore it must be anticipated that a vast network of mains and cables remains the only feasible alternative. That being so, provision must be made for this network as a definite part of any town building or rebuilding (Figs. 4, Plate 1); the method hitherto adopted of burying pipes, sewers, and cables under carriageways and paved footways should be completely discontinued and they should be laid under strips of unbuilt-upon land specially reserved for the purpose, so that excavation for renewal or repair will in no way affect the normal use of property, roads, or footways. Preferably these reservations should be completely independent of the road system, the mains crossing the roads only in tunnels, in order that unsightly, obstructive, and costly excavations should not be regularly imposed upon the whole of the population. If, however, it is necessary to lay them along roads, the mains should be under unpaved reservations wide enough to allow for repairs without any interference with other road uses.

A further point of importance is that complete needs should be anticipated so far as possible; the necessity of supplementing a main by another or its substitution by one of larger size should be recognized as a serious error of judgement. The pattern of future planning and the limitation of urban growth should enable proper estimating to be done quite reasonably.

Very little improvement seems necessary in methods of distribution or carriage in the cases of gas, water, electricity, or sewage, but house-to-house collection of refuse still remains a rather primitive procedure. Methods of waterborne carriage in pipes have been explored, the Garchey system being probably the most advanced. This system is installed on some of the newer developments in France, whilst the most important example in Great Britain is at the Quarry Hill estate, Leeds. The plant is considerable, consisting of a special disposal sink in each building or house, connected by pipes of large diameter to underground suction-chambers from which the refuse is drawn to a central disposal-station where it is de-watered by pressure and then burned. At Leeds the station is combined with a communal laundry and the scheme extends to 938 tenement dwellings on a site of 26 acres.

Any considerable extension of such a system, for example, to a small

town of 50,000 population, would necessitate the use of an inordinate quantity of water and a number of treatment plants or a very unwieldy system of carriers; and probably it is for this and similar reasons that the old method survives.

Additional Services.

The conditions of modern life and the ever-increasing standard of living continually bring forward new and improving facilities for comfort and business and render them available to an increasing proportion of the population. The more common use of electricity has made it possible to utilize innumerable appliances in homes and offices, and there can be no doubt that their number will increase. It seems highly desirable, therefore, that when estimating capacities of electric cables and generating plants, some attempt should be made to calculate on a generous basis in order to avoid frequent replacement and extension of plant.

Some of the services which are commonly supplied to all new residential buildings in America are worthy of consideration, because undoubtedly their use will become general also in Great Britain.

The Telephone.—For many years the overhead system of supply of telephone facilities has been an offence against the aesthetic values of our towns, and equally an eyesore in country districts, and the recent attempt to use double insulated wiring, which is much more visible than the single bare wires, indicates a complete lack of appreciation of anything but utility and economy. Important as these are, there are other factors equally, and perhaps more, important.

Telephone cables should be laid as an underground network, as also should the cables for low- and high-tension electricity. They should be designed to connect with every building in the town and there should be a sufficient surplus to furnish additional lines where needed in industrial and commercial areas.

Radio-transmission.—In districts where transmission by direct lines from a central receiver has been tried, a considerable measure of success has been achieved. This service may be possible by using telephone networks, failing which provision should be made by underground lines or by ducting at the time of redevelopment.

Refrigeration and air conditioning.—These services may well become common in towns of the future, but they usually depend upon individual plants and need only be anticipated by capacity estimating in electric-supply cables.

Heating.—The expansion of district heating in Germany and Russia during the past twenty years is due, in all probability, to the large amount of rebuilding in those countries and to a much greater climatic need than prevails in Great Britain, but it is possible that one of these reasons alone (extensive building and rebuilding) will necessitate serious consideration

of the subject in this country. The three main advantages claimed for district heating are fuel economy, a higher standard of comfort, and purification of the atmosphere. The first two can be challenged if applied to particular cases, but the last is undoubtedly true. The quantity of coal burned by the poorer families is usually less than 2 cwt. per week in winter and very little indeed in summer. It is used to heat the living-room, to supply domestic hot water, and also for cooking purposes. Whilst central heating definitely would raise the temperature of the whole house, it is doubtful whether it would eliminate the use of an open fire, whereas, based upon the requirements of a three-apartment house, a central plant would involve the consumption of more than 3½ tons of coal per annum for each house. On the score of comfort and health opinion is divided. Perhaps the most unfortunate features of district heating are the necessity for an additional network of pipes of a very bulky character and the cost of the service to the consumer which, on the basis of the three-apartment house, could hardly be less than 3*s*. 6*d*. per week per family.

Either of these disadvantages could be overcome, the first by district heating by electricity, and the second by combining the production of hot water with the generation of electricity. If it were possible to supply electricity at ⅛*d*. per unit, there would be no need to use hot water for heating, and the same service could be rendered by individual immersion heaters for domestic hot water and electric heating units in the rooms. On the other hand, if electricity generating stations were conveniently situated, the supply of hot water to some urban areas would be possible at a much cheaper rate.

Two interesting Papers on this subject have been presented by Mr. S. B. Donkin, M. Inst. C.E.[1], and Mr. Donald V. H. Smith[2].

The problem is one which requires unbiased examination, and it may well be that the advantages outweigh the disadvantages.

Planning for Future Wars.

Much has been said and written about the necessity of considering, in every project for the future, the possibility of war and the need for providing adequate protection in the design of structures. These considerations fall mainly into two categories—dispersal or camouflage and structural protection. The logical conclusion of both lies in the building of our future towns underground—and a long way underground; but without this unthinkable expedient it is possible to effect a certain measure of dispersal and a measure of protection against explosive and incendiary

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[1] "Industrial, Agricultural, and Domestic Heating, with Electricity as a By-Product." Journal Inst. C.E., vol. 1 (Session 1935–36), p. 378 (January 1936).

[2] "District Heating and its Relation to Housing and Town Planning." Trans. Instn. Engrs. and Shipbuilders in Scotland, vol. 84 (1940–41), p. 163.

bombs. The chief consideration is whether either course is worth whild apart from amenity, convenience, and ordinary structural improvement.

It is impossible, without serious economic dislocation, to disperse our large cities and towns beyond a limited degree, and in consequence they will remain major targets for enemy action. New towns, however, will be less dense and the considerations of amenity will provide a certain amount of camouflage by the retention and planting of trees and shrubs.

Structurally, it is impossible to give protection against the unknown weapons of the future, but modern methods of construction, by the general use of concrete and steel, will achieve greater resistance to the weapons in use to-day, and also against fire. From the ethical point of view it is a very serious condemnation at the present time even to contemplate the necessity of any such provision.

The Engineer's Part.

Town and country planning is not an exact science, neither is it an imaginative art. It is, or should be, a product of accumulated experience of social requirements scientifically applied and presented in an artistic form; the construction which follows the plan requires the application of good design and good workmanship. Consequently the reconstruction of our towns and cities, whether damaged or not, and the building of new ones, is an undertaking which calls for the collaboration of several professions and consultation with many others.

Actual experience in the making of town plans, and of the innumerable factors and difficulties which have to be overcome, is comparatively rare in Great Britain, and is confined mainly to the Surveyors to local authorities and their assistants, who are usually trained as engineers, and sometimes also as architects. In addition a small number of engineers, architects, and estate surveyors have carried out this work in the capacity of consultants.

This type of planning is so closely interwoven with the constructional sciences and arts that it can be performed with any degree of success only by persons who have been properly trained in the common elements of engineering, architecture, and surveying and who also have a wide experience of the many factors governing the daily life of communities.

It follows, therefore, that engineers have a heavy responsibility in the matter of town and country planning because, collectively, they have the greatest accumulation of experience in the subject, allied to the right type of basic training; but the task calls also for the exercise of other than scientific faculties. Imagination, an understanding of aesthetic values administrative and managerial ability, and a willingness to seek advice on many subjects, such as economics, sociology, agriculture, etc., are essentia in the consideration of balanced planning.

In the construction and reconstruction following the making of the

plans the engineer is everywhere concerned. The work will be of all types and on all scales—national, regional, and local. It will range from the design and construction of a system of national highways proportioned to carry the traffic of a reorganized industry to the rebuilding of the dock installations of London, Liverpool, and Hull; from the many new and specialized plants required by manufacturers, and for public utility supply in old and new towns, to the construction of the buildings—civic, industrial, and domestic—which will be required to replace those damaged by enemy action and those, still more numerous, which will require deliberate destruction and replacement in the process of planning and reconstruction.

New towns must be built and old ones rebuilt, railways, canals, and facilities for air-borne traffic must be extended and improved, and bridges over rivers and tunnels under them will be required to complete the new communication systems. In fact, all those works will be needed which engineers have carried out in the past, with many new ones which may be indicated by a more comprehensive application of engineering science.

Any attempt at a catalogue is useless and unnecessary, but it is probably correct to assert that engineering science and works bear so preponderant a part in town and country planning and reconstruction that the terms are almost synonymous.

While continuing to keep abreast of advancing scientific knowledge, engineers should learn to think on a wider plane. The acknowledgement of the relation between local and regional schemes and, in turn, of their place in a national pattern, is likely to be one of the chief factors in post-war organization, and the engineer must be prepared to advise and, if necessary, educate public opinion in the wisdom of this wider conception.

There is little need to stress this necessity. Everywhere there are examples of the narrower view which has been the rule rather than the exception—water pipe lines isolated from adjacent areas of possible supply, and of sizes sufficient only to feed their distant objectives; multiplicity of sewerage schemes in congested districts, with sewage-disposal plants overlooking each other; factories crowded into areas already congested, or robbing the natural beauty of rural land of its aesthetic, recreative, and productive values; electricity-supply plants far from urban centres where they could give added advantage to large communities; pylons and overhead networks at the price of aesthetic discomfiture to many people.

Considerations such as these will enter more and more into post-war work, and the engineer, equipped already with the best possible basic training, should equip himself still further by cultivating imagination, aesthetic appreciation, and a more general understanding of communal needs and values.

The Paper is accompanied by four sheets of drawings, from which Plate 1 has been prepared.

Discussion.

The Author, in introducing his Paper, exhibited a number of lantern slides. He observed that the subject could not be reduced to exact scientific formulas, but he had tried to show the trend of modern thought, in order that the Paper might present the atmosphere and the organization within which reconstruction after the war would possibly—he would like to think probably—be carried out.

The subject of town and country planning and the reconstruction at which it aimed was so large a subject and so fundamental that it was probably basic to the work of every member of The Institution, and of most men connected professionally with building in Great Britain and elsewhere.

He thought that the framework within which planning and reconstruction were likely to be carried out, was very important, particularly to the younger members of The Institution, whose lifetime's work was involved, because some knowledge of the conditions under which they were likely to work was very important, and there was no doubt that a larger conception of the relative importance of individual projects would be one of the underlying principles of post-war work.

The Council had recently interested itself in a remarkable manner in some of the larger conceptions to which he had referred. The lectures which had been instituted at Cambridge and throughout the country and the Papers which had been presented to The Institution on such matters as aesthetics, general business management, and educational subjects, were directly related to the subjects of town and country planning and eventual reconstruction.

Much of the organization about which experts had been talking for the past 20 or 30 years had, by a system which he might call democratic progression, been embodied in legislation, and there was now a national recognition of the necessity for national planning.

In his Paper he had steered a course between the ideas of what might be called extreme conservatism and its opposite, which he had heard very aptly described as "long hair and sandals", that was, the experiments and theories of the faddist. Probably much in the Paper would seem advanced, but it contained nothing so far advanced as many of the ideas which were being urged at the present time. There was, he thought, a foundation which was workable and which was likely to be productive of results, and he had ventured to put it forward not only as a possibility but also to some extent as a probability. He had mentioned four fundamentals of planning and reconstruction after the war, the first

two of which should precede the formulation of a complete and orderly plan for the country, whilst the other two should govern the reconstruction. It mattered not under what financial conditions or under what conditions of land tenure the work was done; they should not affect the plan itself, because that should be formulated to an ideal, but they would affect the progress of reconstruction. If the two great problems of finance and land tenure could be solved, the programme of reconstruction might mean something within the lifetime of, at all events, the younger members of The Institution; but, if they were not solved, the danger might arise of a programme being entered upon which would take so long to carry out that great changes might take place in the meantime.

The President thought that all would recognize that the Paper was a work of high distinction. The Author was a high authority on the subject, and that was abundantly evident in the Paper. Under war conditions, and owing to censorship restrictions, Papers discussed at The Institution were necessarily fewer, but he was sure it would be agreed that, particularly as exemplified by the present Paper, they had certainly not been reduced in quality.

Mr. T. Peirson Frank hoped that the Paper and the discussion on it would tend to show the great part which should be played in planning, both local and national, by members of The Institution, and particularly by the younger ones who were specializing in town planning.

On p. 235 the Author had said, referring to the replanning by the Italians of their larger towns some years ago: "It is difficult to trace the actual cause of these activities." In 1929 an International Congress was held in Rome, and Mr. Frank had acted as honorary reporter of one of the meetings, at which Professor Chiodi, who represented the Italian views, said that the trouble in Italy was practically identical with that experienced in Great Britain; during the past century the towns in Italy had developed like "stains of oil", but an effort was being made to change that monocentric development to self-contained units separated by very considerable open spaces. The subject of the space between a large town and its satellite town had also arisen in cross-examination when the Chamber of Trade of Welwyn Garden City had attended a meeting in London. The question was asked as to the distance they thought they ought to be from their larger town (in that case, London), and the reply was that Welwyn was too far away from the town to which it was supposed to be a satellite.

Those who had had in the past to deal with regional planning rather than town planning had doubtless felt the absolute necessity for some sort of foundation upon which the lay-out of a regional plan could be based. That need had been expressed on other occasions, but up to the present no national structure on which a regional plan could be founded had become evident.

Mr. Frank would like regional planning to be rather more closely defined, for the following reason. Ten years ago, when the topic was

under consideration, nearly all of the regions contemplated were about 20, or perhaps 30, miles around some of the larger towns. But those regions were not regions in the same sense as the present civil defence areas, which were regionally controlled. Which of those two views had the Author had in mind ?

In dealing with planning organization the Author had expressed the view (p. 242) that : " the plans themselves should be a matter for local preparation ; they should be prepared by local persons having an intimate knowledge of local factors—preferably by persons whose life and circumstances are parts of the plan itself." Mr. Frank thought that the men who had that most intimate knowledge were the engineers to the local authorities. Hitherto probably about 80 per cent. of the town planning schemes had been prepared by them, and they could therefore assist considerably in the larger national planning and reconstruction.

In dealing with detail planning units the Author had given (p. 243) two solutions for the problems encountered. The first was : " the revision of local authorities' boundaries on a regional basis." Mr. Frank was not quite sure what the Author meant by " regional " in that connexion, but that solution would be quite useful ; it was the one which the Italians and others had adopted ; but those who had taken part in any of the very keen fights for an extension of a borough boundary would know that it was not a very happy solution in Great Britain. One could not imagine two virile towns such as Leeds and Bradford being merged with each other. The problem was not one for engineers, but had to be dealt with by those who were concerned with the formation of the local government structure. The second solution suggested by the Author seemed more likely to meet with acceptance, but Mr. Frank thought that it would be necessary to add " with powers to implement the decisions." Some of the most successful work had been carried out by regions which had had sub-committees of the borough engineers and surveyors working under a joint committee of the local authorities.

A difficulty arose in the creation of a satellite town, which had been noticed by Lord Marley's Committee on Garden Cities and Satellite Towns. Usually the large town wanted to be able to expand, and therefore wished its satellite town to be some little distance away. Little difficulty had been experienced in the days when money could be borrowed from the Government free of interest for the purpose of financing the satellite town, as in the case of Welwyn, but such facilities were not available to-day. The County Council concerned would, if it were rich enough, assist in financing the satellite town—provided that that town was not planned to be so large as to become a county borough !

He agreed with the Author's remarks on ring roads. When Mr. Pybus was Minister of Transport he took quite a bold step and decided that part of Marylebone Road was to be a ring road and that all through omnibuses, Green Line coaches, and so on, should be kept out of the

centre of London. Mr. Frank considered that passengers travelling in public conveyances, such as omnibuses, should have the right of free transfer to omnibuses, etc., running within the inner circle. By that means the pressure within the inner circle could be relieved and only as many vehicles used as were necessary to convey passengers within that area.

With regard to heating and ventilation, the Author and he (with others) had recommended an impartial investigation, because they believed that probably one of the greatest national economies could be effected by adopting a system of district heating.

The Author had mentioned the "multiplicity of sewerage schemes in congested districts." Mr. Frank knew of no more congested district in Britain than the area within 25 miles from Charing Cross. In 1931–32 that area contained about 200 sewage-disposal works, two of which —operated by the London County Council—served more than 5½ million people, whilst the remainder served about 3½ million people. Those works had not been constructed at the dictates of engineers: the local government structure had caused that multiplicity of unnecessary, unsightly, and sometimes unsavoury works. The cost per head per annum for the two large works was 1*s*. 9½*d*., whereas, for the other works, in the sixty-four districts that furnished returns the cost per head per annum ranged from 2*s*. 2*d*. to 3*s*. 4*d*.

Sir Frederick Cook said that whilst he agreed with nearly all that the Author had said on the engineering aspects of the subject, he was inclined to dissent from the view that no urgent need for town planning had been apparent in Great Britain prior to 1918. The narrow and tortuous streets of our old cities had left us with a heritage which only the recent visitations that everyone deplored had provided an opportunity for improving in the comprehensive manner that was generally desired. Again, there were the conditions which arose as a result of the industrial revolution—the development of towns with mean streets and appalling buildings—which, as had been aptly said, gave rise to conditions in which people had to live, "divorced from nature, and unrelieved by art."

The Author had referred with an enviable freedom to the effect upon the development of the country of our system of land tenure; and he might well have added the building development which the country had suffered for so long—much earlier than from 1918—whereby the arterial roads were regarded not as main traffic routes but rather as furnishing desirable building plots upon which dwelling-houses could be subsequently erected. In that connexion it would be unfair not to mention the extraordinarily good work which had been done by certain large landowners on their estates, particularly in residential towns.

The Author had suggested four basic principles as essential to the organization for reconstruction, and Sir Frederick wished to suggest another, namely, transport. He thought that the means of communi-

cation should be regarded as an essential part, and indeed as the framework, of a plan. He was considering transport not from any one point of view, but as a whole. The spirit of co-operation had been singularly lacking. The development of canals had been hindered, if not stopped, by a form of control which was inimical to co-operation, whilst even in recent years the controversy—at times almost bitter—between road and rail had been unfortunate, and had led people away from the real crux of the matter, namely, that all forms of transport—road, rail, water, and now air—were essential, each in its own way and by its own means, to the industrial and social development of the country. Each should be regarded not separately, but rather as complementary to the others and forming an essential part of the whole system.

The Author had referred to the necessity, in the interests of trade and industry, of providing a balance which would not be subject to periodic depression or boom, and he cited Birmingham as a fortunate instance in that respect. Perhaps that condition in Birmingham was largely fortuitous. Geological as well as geographical conditions had to be considered, and those were conditions which could not be altered. The Author had suggested, presumably as a solution of the problem, that existing industries and centres of population should be supplemented or decentralized without regard to the effect upon purely local rates and property values. That was indeed a bold suggestion, but psychological, as well as material, conditions had to be taken into account. Those who had had experience in 1929 and a year or two afterwards, of moving people from one town to another, in order to find employment for them, realized the enormous but easily understandable objections which men raised to being taken away from an occupation which they had learned from their fathers and in which their families had been engaged for generations, and to removal from a neighbourhood in which they had been born and bred. It was obviously right that in such cases the people should receive the most sympathetic and kindly consideration. That was a matter perhaps for the politician, and not for the engineer, but it was indeed essential that the considerations which he had mentioned should be kept in view. He need only refer to such matters as the working out of minerals and the transference of trade from one district to another by reason of economic or other considerations, over which the people concerned, and the workers in particular, had no manner of control.

Mr. Frank had referred to the question of the machinery by which planning should be prepared and carried out, and the Author was evidently of the opinion that the best method to adopt was that of regional organization. Possibly that was the best machinery for preparing plans, but he doubted whether it could be left to the local authorities. It should be remembered that many variables operated amongst the constituent members of a region—variations in area, in population, in ratable value, and so forth—and, whilst some might find it comparatively easy to

carry out the recommendations of the regional organization, many others might find it beyond their means. The fundamental difficulties, to which Mr. Frank had alluded, were dependent upon and had arisen from the structure of local government. Such factors had led to the passing of the Trunk Roads Act in 1936, whereby certain roads became the responsibility of the Government instead of that of the numerous highway authorities through whose areas the roads passed. As the Author had implied, it was very unfortunate that the outbreak of war had put a stop to the work which was already in hand in that connexion.

In giving effect to regional planning, the spread of expenditure was not the only desideratum to be remembered. The burden should be equalized over the region as a whole on the basis of capacity to pay. The problem was perhaps beyond the scope of the engineer, but the Author had wisely remarked that in all such matters the engineer should undertake to educate the public. They would have to be dealt with before planning could be made really effective ; otherwise those responsible would fall into the not uncommon error of trying to develop tactics in advance of strategy.

"Planning for future wars" was a prospect which few people could contemplate, and which none could contemplate with equanimity. If Great Britain were to be planned on the supposition that at any moment it might be attacked from the air, or that an enemy might land on its shores, surely that was a negation of all for which the people were now fighting ; and nothing that they could do, no money that they could spend, no personal sacrifice that they could make, would be too great if it would save the country from that calamity.

The Author had discussed the part which the engineer should play in post-war planning and the qualities which he should possess. Of all those qualities none was more imperative than that of willingness to take advice. Planning was not the function of the engineer alone. By reason of his training and experience, no technical man was better qualified than the engineer to perform that task, although some matters had to be borne in mind with which perhaps he was not best qualified to deal. The Author had shown that in the matter of planning the engineer was capable of covering a wide field, and engineers should look forward to the time when they would accomplish the end they had in view, that of making Great Britain a better country in which to live.

Mr. D. H. Brown observed that in the section of the Paper dealing with a national skeleton plan, the Author had suggested that it would be desirable to divide the country into a number of regions to deal with the skeleton plan for communications. Surely that point was already met by the Divisional Department of the Ministry of War Transport ? The headquarters of the Ministry dealt with all systems of transport and should therefore be the body to deal with the skeleton plan for communications, and Mr. Brown did not think that there was any need for further regionalization.

With regard to the approval of detail plans, if national control was too rigid or detailed there was a danger of standardization becoming a fetish which had little regard for local feelings and traditions. Whatever else might be said of the past development in Great Britain, it had to be admitted that in many areas the local building tradition had influenced the trend of development to the advantage of the country as a whole. With an increasing tendency for standardization throughout the whole country, the expression of local character and tradition might be submerged in a uniform standard of design devoid of any expression other than regularity.

The Author had referred to the possibility of the distribution of water-supply on a national scale. Quite apart from the economic and technical considerations, which were extremely complicated, a very important question of principle would also be involved, namely, the allocation of the costs of such a scheme. It would be appreciated that Mr. Brown was speaking as a county council official and not as a borough official or a water engineer. There was little comparison between the generation and distribution of electricity on a national scale and water-supply on similar lines, because, whilst everyone in the country would probably take advantage of the electrical scheme, in many rural areas large numbers of people were able to provide themselves with a sufficient and wholesome water-supply merely at the cost of sinking a well on their own ground. It could not reasonably be expected that such people would be prepared to contribute to the cost of a national water-supply scheme, even if that was found to be a practical possibility.

He was not quite clear as to the exact impression which the Author wished to convey in the fourth paragraph of the section on "Detail Planning Units" (p. 243, *ante*). A number of county boroughs in the country had large areas of rural land within their own boundaries, and in those cases there would appear to be no lack of balance between urban and rural considerations within the same county borough. If the Author meant that those areas were insufficient and that a much larger area was necessary to give a proper balance to detailed planning units, could he give some idea of the area of land which, in his opinion, should be included within a county borough planning unit for the purpose of effecting a balance in the planning outlook?

The Author had suggested that the county, although a much better planning unit as regards size, lacked the advantage of intensive urban development, with its consequent ratable value. Mr. Brown doubted whether that statement would find general agreement, for, so far as Warwickshire was concerned, a considerable intensive urban development in the county planning area had arisen from the proximity of Birmingham and Coventry. The type of development which had taken place had admittedly brought ratable value to the county; but the expenditure on the provision of such services as roads, sewers, schools, and so forth, had

frequently outweighed the income which was derived from the urban development, which was, therefore, not altogether a blessing since it carried heavy responsibilities with it. He would expect a similar position to exist in the home counties adjoining London, and also in the industrial areas of the north-west of the country. If, however, the Author meant that lack of ratable value in a county necessarily tended to cripple the preparation or carrying out of planning schemes, Mr. Brown would be glad to know the Author's reasons for that view.

In Warwickshire planning was being carried out on a county basis, by agreement with the local authorities working under four Executive Committees, which (with the exception of three municipal boroughs, that were preparing their own schemes) covered the whole administrative county. The County Council and the local authorities had representatives upon the Executive Committees, and Mr. Brown acted as Honorary Surveyor to the Committees. The schemes were prepared by a planning staff in his department, and the whole cost of the work was met by the County Council. By that arrangement local knowledge and interest were retained, and on the whole the system had worked fairly satisfactorily. Naturally in such cases local difficulties would arise. In Warwickshire one large urban area desired to avoid any industrial development in the way of factories, and in such a case there seemed to be a tendency on the part of the other authorities not to wish to argue with the authority in question as to whether the line it took up was right or wrong. He believed, however, that the bulk of the members of the Committee—certainly the technical members—thought that it would have been better for the locality in question to accept a certain measure of industrial development rather than hope to increase its population to 70,000 or 80,000 without having any industry within its boundaries. Before the scheme had been completed the war had started and had forced a good deal of industry into the area, so that the problem had solved itself.

He would be interested if the Author would amplify his views on regional collaboration, particularly as to when it could be stated with assurance that existing towns had grown too large for the provision of adequate amenities for the inhabitants, and also how it was suggested that the process of thinning out would be effected.

Whilst the establishment of new towns was very desirable in theory, considerable difficulty was involved in reconciling the various industrial, social, and domestic interests involved. Moreover, the tendency of the population of Great Britain to remain stable, with an increasing proportion of older people, would seem to confine the establishment of new towns within very definite limits, despite the drift of the younger people to the south and to the midland industrial areas, during the past few years, which constituted a rather different problem.

The dispersal of industry was a closely allied subject. The authorities in Warwickshire had been in direct contact with the problem during the

past 18 months and had been able to assist many industrial concern in their search for existing buildings for use as factories, stores, and so forth, and with advice upon new sites for factories. In most cases where new factories had been erected the sites had been within a mile or two of existing industrial towns, or on the fringe of smaller towns, as the chief necessity had been adequate supplies of gas, water, and electricity, in addition to transport facilities for the workpeople. Alternatively, in a few cases quite small buildings had been taken in or near villages, and machines installed to employ twenty to thirty people, most of whom were drawn from the locality. In one or two cases fairly large new factories had been erected in country districts where public services were available but large numbers of workpeople had had to travel long distances to and from their work, and it would seem doubtful whether they would be prepared to continue to do that in peace time, or whether their wives and families would be willing to live in quiet country districts once the dangers and worries of air raids had passed, even if houses were provided. Possibly the dispersal of industry could be more successfully carried out by setting up new industries, as extensions of existing smaller towns, in parts of the country which were at present subject to depressions owing to their having only one type of industrial activity. That would avoid the necessity of moving people away from their existing homes and associations. Alternatively, if the trade was one which for commercial reasons could be conducted most economically and efficiently in a certain limited area of the country, that could most conveniently be done by dispersal to smaller towns within that area.

The more or less compulsory removal of people from one part of the country to another was a difficult, delicate, and expensive matter, which would need very careful consideration if a contented community and successful industries were to be established.

Mr. Brown agreed that planning authorities should have power to require private building or rebuilding to proceed according to a time programme, and should exercise control over initial building construction. One of the greatest drawbacks of the existing planning system was the lack of official encouragement to the practice of time-setting, which would allow the fullest advantage to be derived from existing services and the extension of them before development could be proceeded with in other localities, thereby reducing the cost to local authorities of the provision of uneconomic services.

Mr. E. H. Ford observed that the following quotation from a recent speech by a Cabinet Minister indicated the growing recognition of the part which the engineer had to play in the development and planning of modern cities: "The population of a large modern city could not exist without the many services performed by the engineer, and the growth and importance of his work is indicated by the large amount of money annually expended on these services. There are, in fact, few matters in municipal administra

tion that do not directly or indirectly concern the engineer." He thought that that was borne out in the Paper.

The Author had asserted that "Great disasters and major wars frequently have resulted in considerable improvement in the physical standards of the people whose homes and properties have suffered damage." Mr. Ford would prefer the use of the word "material" rather than "physical"; but, even with that emendation, he did not agree with the statement. Many people considered that during the past 25 years they had seen a great retrogression of real values in Great Britain. He concurred that the peace-time programme of slum clearance and reconstruction did not exercise the popular imagination, but he thought that people would want to see the devastated towns and villages brought to life again as quickly as possible. He therefore regarded it as very important that practical and workable schemes should be prepared, so that reconstruction would not be delayed by the formulation of more ideal plans which would take much longer to put into operation. The danger was that people would become impatient and the country would drift into inferior redevelopment schemes.

The Author had been very bold in his suggestions as to land nationalization. Mr. Ford could not regard the purchase by the Government of mineral rights as a similar matter to the nationalization of the surface of the land. He considered that it would be unfortunate if replanning were taken into the political arena to such an extent as was suggested in some quarters. He agreed that it might be *easier* perhaps for a civil or municipal service to plan land which belonged either to the Government or to the municipality, but he doubted whether planning by such bodies always led to the best results. There was a danger of entering into a phase of national life where freedom and individuality would be enmeshed and bound by fresh legislation, the object of which would doubtless be, in the opinion of the present generation, the uplifting of the people; but, unless a very long vision were applied and great caution exercised, the result might be the exact opposite.

The British people could not let themselves drift away from their national characteristics. They were a cheerful people, humorous, self-reliant, perhaps reticent sometimes; they loved sport, and they loved animals and gardens and allotments. Another problem was that of the "hiker"; his path should be made easy—but not too easy. The roads were used by many unpleasant people, such as the "road hog" and those who spread litter on the countryside, and they had to be considered in any question of planning. Again, if the countryside were not to be spoiled, restrictions might have to be imposed upon speculators and others. The Author had referred to the education of the people; but what was meant by education? There would be black sheep, rogues, and Calibans for a very long time. At a conference which Mr. Ford had attended, a remark had been made which had struck him very forcibly, namely, that

the country would still have to have "localized hells." In plannin provision would have to be made for all types of mind and for the enjoy ment of all kinds of people. It might not be possible to do away with a the black country and other "localized hells," but efforts should be mad to make them purgatories rather than hells.

Referring to the Author's remarks on Russia, Mr. Ford thought th best thing that could be done was to observe and learn from the failure in other countries. He could not think that English people woul ever go in for the orgies of flat building which had taken place in Italy Germany, and France, and it was certainly not desirable that they shoul turn to the Nazi type of architecture. The President of the Royal Insti tute of British Architects had said that he could not understand hov architects in Italy, living as they did among the glorious buildings of th past, could construct such atrocities. There was a danger of that bein done in Great Britain also, and it was necessary to guard against it.

He considered that too great a use of the drawing board, the T-square and the pencil should be avoided. He was always very suspicious of plan which looked pleasant and pretty on paper, and he felt instinctivel that something was wrong with it. Diagrammatic plans and geometrica designs for housing estates were prepared without any relation to th engineering problems involved.

The Author had expressed the view that industrial expansion, agri cultural policy, land tenure and finance were subjects "not within th scope of town and country planning"; but Mr. Ford thought that the should be.

He did not think that more new towns were needed. Many of th younger generation employed their draughtsmanship enthusiastically i designing new towns, but the question should be asked whether those nev towns were wanted and whether people would be happy in them if they wer built. Those who lived in the "desirable residential suburb" or th "desirable residential estate" were not always the happiest people.

The Author had raised a very interesting point by his statement tha "the road constitutes a construction member or backbone of the redevelop ment plan." As Sir Frederick Cook was present, Mr. Ford would plea that the Government should define trunk roads and motor roads as soo as possible, because, until that was done, planners could not make an progress with their redevelopment plans, even in central areas, since th road scheme formed the backbone of the whole plan.

Mr. Hilaire Belloc had truly said that imagination was the greatest gif that God had given to men, for by it alone was religion conceivable Imagination, in which Mr. Ford included not only the features to whic he had already alluded but also the human values and everything whic the people of Britain held dear, should lie at the base of all planning.

The varying characteristics of the English, Welsh, Scottish, and Iris peoples, and the outlook of each of them and of the country and tow

dwellers, should be exemplified in the physical planning and building of town, house, farm, and workshop.

Mr. S. B. Donkin observed that he appreciated the Author's proposal not to bury service pipes, cables, etc., in the roadways or footways in new model towns or villages, but to provide subways; or, if that were too expensive, to provide tunnels where crossing roads, and otherwise reserve strips of land on each side of each road so that buried service pipes and cables could be exposed for repairs or extensions without interference with traffic. The facilities offered by subways and tunnels made district heating and the supply of hot water considerably more economic and simple to install.

The Author considered that telephone, low-tension, and high-tension electricity cables should be underground. That was the correct ideal, but in practice it meant that the distribution system might cost from three to ten times as much as for overhead distribution (depending upon the voltage of transmission) and would affect the cost of electricity unless the local urban or county authority responsible for the new plan would provide the subways or tunnels without rental to the public utility undertakings.

Mr. Donkin wished to emphasize the desirability of district heating combined with the supply of electricity for a new town whenever a generating station was reasonably available, or its erection was permissible. It should be borne in mind that such district heating could be effective only if there were a reasonable density of housing to provide economy in distribution.

A supply of hot water should be made available, as well as provision of space heating, and both of those supplies should be given from the same source by means of hot water and through one service. Mr. A. E. Margolis had written a number of articles on that subject, and in view of his pre-war experience in Hamburg his figures were worthy of very careful consideration and attention.

For a model township such as that referred to by the Author, with 100,000 inhabitants and with some industry and municipal buildings, there could be, with the combination of the supply of electricity with heat, a saving in coal amounting to 100,000 tons per annum, in comparison with the separate and independent supply of electricity at the lowest possible present-day costs, together with the supply of coal for heating all the domestic and other premises in the town by open grates and by independent enclosed boilers for hot water. That saving of coal would represent about 1 ton per head of population per annum.

The Author had asserted that the cost of a service to the consumer for heating might be 3*s*. 6*d*. per week as an on-charge to the cost of the heat for a three-roomed house. Mr. Margolis had had some experience with such services, and with his design of a one-pipe system for both space heating and hot water, which he advocated, the price would be very much lower

than that, and he had told Mr. Donkin that it might even represent the total cost per week for heat, hot water, and the service.

In 1936 [1] Mr. Donkin had demonstrated that a model township of 100,000 inhabitants could be provided with cheap electricity and heat for industrial and domestic purposes at a low and attractive cost and was a remunerative proposition. It was all the more economic, as he had said in his Presidential Address[2], if the ratio of the heat quantity to the quantity of electricity required was high. That ratio for the model town of 100,000 inhabitants referred to by the Author would be about 4½ to 1 (heat to electricity) in heat units.

The following data had been used in giving the figures mentioned above: For a model township of 100,000 inhabitants with industry, hospitals, schools, and public buildings there should be a consumption of 800 kilowatt-hours of electricity per person per annum for power, light, and heat. (The load factor of the system might be 33·3 per cent. giving a peak load for electricity of 28,000 kilowatts.) 800 kilowatt-hours per person per annum covered sufficient electricity to provide for additional electric heating in cold weather and other special cases.

The space heating and heat required to provide hot water as at present, with coal fires and enclosed boilers, had been taken at 4½ tons of coal per annum for a house to accommodate three persons. That figure had been given by Mr. Donald V. H. Smith in a recent Paper presented to the Institution of Engineers and Shipbuilders in Scotland [3] : it represented, for the Author's model township, about 1½ ton per head of population per annum, and corresponded reasonably well with the consumption of coal for domestic purposes given in the Mines Department's Annual Reports.

The efficiency for open fires and enclosed hot-water boilers was taken as 30 per cent. The efficiency of the distribution of heat was taken as 80 per cent.

The saving was so large that the cost of providing the district heating and hot water service system could very easily be covered, and anyhow it would be covered by the charges made to the consumer for heat and electricity, so that there was a net gain to the country in the saving of coal.

Mr. Donkin admitted that the system could not be applied immediately throughout the country; but wherever a new township was to be built or reconstructed; wherever an electricity works was available, or could be built; and wherever subways or other special provisions were made for public utility services, a satisfactory case could be made out for the combination of the supplies of electricity, space heating, and hot water.

Mr. R. H. Buckley inquired whether Birmingham had been in an

[1] "Industrial, Agricultural, and Domestic Heating, with Electricity as a By-Product." Journal Inst. C.E., vol. 1 (1935–36), p. 378 (Jan. 1936).

[2] Journal Inst. C.E., vol. 7 (1937–38), p. 2 (Nov. 1937).

[3] "District Heating and its Relation to Housing and Town Planning", Trans. Inst. Engrs. & Shipbuilders in Scotland, vol. 84 (1940–41), p. 163.

advanced stage of town planning before the war, whether any scheme had been actually in operation, and whether industry had been allowed to be restarted in its original position.

Restrictions on land permitted by legislation carried with them a liability for compensation, which usually terrified councils. When they were told that certain restrictions should be imposed, they nearly always said: "What is it going to cost?" And that fear prevented the benefits of the legislation being secured.

He did not consider that Great Britain had done well at town planning, especially with regard to the provision of great trunk roads.

He reviewed briefly the history of town planning in Essex. Between 1920 and 1930 the south-eastern part of the county was shockingly developed: there were no by-laws in the rural districts and no control.

Under the Local Government Act of 1929 the County Council obtained control of all the roads in the rural districts, and inquiries were held with regard to the alteration of boundaries, with the result that large rural and large urban districts were created. That Act contained some very useful provisions and enabled the County Council to set up Regional Executive Committees. Three Regions were formed, comprising in all twenty-eight local authorities, and those who had had experience of the difficulty of persuading small units to forgo their own powers and to combine with others, would realize that it was a great achievement to get twenty-eight local authorities to combine in the work of the Executive Regional Town-Planning Committees. He stressed the word "Executive", because the Committees must be executive if they were to be useful. An important point was that the county council paid half the cost. Between 1925 and 1935 it spent an average of £1,000,000 per year on roads, and in 1935 it spent £16,000 on town planning.

In July 1933 the Essex County Council Act came into operation, under which the county council obtained valuable powers for land acquisition for green belt and open spaces, the clearing of waterways, and the prevention of ribbon development. It also provided that on the deposit of a plan with the local authority, a notice could be served on the owner of the property, requiring him to provide reasonable means of access before a house was sold, let, or occupied. That went a long way to stop sporadic development.

He was interested to read of the numbers of professional men engaged in town planning in Russia. Town planning was already slow enough in Great Britain, but if so many people had to be consulted it would be difficult to get anything done at all.

He agreed with Mr. Ford that the Author's four basic principles came within the scope of town planning. Industry grew up owing to physical conditions, and doubtless the Author would agree that atmospheric conditions should not be lost sight of. The town-planning schemes in Essex included many reservations of suitable land for agriculture. One

rather unfortunate thing was that the rural district councils, financially assisted, had laid many miles of water-supply pipes, and were disappointed that the land could not be sold for building purposes, so that they could recoup themselves for the expense of the water-mains.

Local authorities would not risk imposing restrictions on land tenure, because of the risk of compensation claims, unless they were assisted by the State, and would not cause large improvements to be carried out unless they were suitably financed.

The Author had suggested that a Ministry of Planning should be set up, and that one of its duties should be the preparation of a national skeleton plan. Whilst Mr. Buckley agreed that one Ministry, such as a Ministry of Works and Planning, should have control, he considered that it should possess executive powers backed by the Treasury, and it was very important that it should be composed of men who thoroughly understood local government. The Author had also referred to the determination of standards and research as being subjects to be dealt with by a Ministry of Planning, and had instanced building by-laws as codes of standards already in existence. Mr. Buckley wondered whether anything could be embodied in the by-laws to prevent the agony of the housewife during frosty weather. Some towns in Essex were frozen up every winter. The supply-pipes to the houses were encased in outside walls and the cisterns and heating cupboards were in the wrong places. Such matters could easily be put right, and it was very important that they should be.

He agreed that detail plans should be prepared by the local authority; and surely national plans could be decided upon and embodied in the local schemes. He also agreed that a special Planning Ministry should approve the detail plans. The Ministry of Health was completely overwhelmed with town planning schemes. For Essex alone twenty-four schemes were in the hands of the Ministry when the war broke out, so that it could easily be realized what an immense number would have to be dealt with from all over the country. He would like to know what had happened to the valuable Report brought out by Sir Charles Bressey. If it was shown to local authorities they were frightened of it, and it was impossible for any local authority to put the very valuable proposals contained in it on a town-planning map unless the Government would undertake to meet all of the liabilities.

He hoped that too many controlling bodies would not be set up. Surely a large county or urban authority, having performed its functions of local government for many decades, had been "duly tried and tested" and should be given greater powers of control, untrammelled by the burden of overriding and unnecessary departments.

He thought that the Trunk Roads Act had been a great success. It had enabled very valuable work to be done in making double carriageways and cycle-tracks, and it was a pity that the war had stopped that work. Local authorities should be exhorted to have schemes in readiness for after

the war. He was pleased to say that Essex had schemes ready which would involve £600,000, and that £350,000 worth of further work could be put in hand in three months.

Whilst congratulating the Author on his interesting and idealistic hopes for the future, he was sure that in Birmingham the Author would be asked this question: "Where's brass coming from?" It was necessary to get down to practical politics. If the Government would say what it wanted, the local authorities would place the restrictions on their maps, subject to 100 per cent. liability being paid by the Government.

*** **Mr. G. L. Groves** considered that by his clear and comprehensive study of some of the reconstruction problems with which engineers would be called upon to deal, the Author had paved the way for other Papers on the same important subject. He hoped that further studies would be forthcoming, because the matter was urgent, the field was wide, and the potential resources of engineering to make the world a better place were almost unlimited. But the value of such Papers would be enhanced considerably by giving them wider publicity than inclusion in the Institution Journal. That suggested the vital question: what could the engineering profession do, in advance of its active participation in reconstruction schemes, to help solve some of the innumerable practical difficulties of the post-war period?

It was significant that the most far-reaching schemes of reconstruction yet achieved had been in "dictator" countries—Russia, Germany, and, to a smaller extent, Italy. Great as might be the needs in the matter of reconstruction on equally broad lines, Mr. Groves feared that the process would not, under the British democratic regime, gather sufficient momentum to drive it through with that thoroughness and dispatch which its great importance merited. But the measure of success which reconstruction eventually achieved would be proportioned in some degree to the extent to which the nation became reconstruction-minded. By that he meant something more than making reconstruction a popular catch-word; nothing less, in fact, than that all responsible citizens should have brought home to them a realization of the necessity for reconstruction, what reconstruction properly applied could do, what it entailed, and how it could be brought about.

A considerable part of the community was ready and anxious to improve its knowledge of things that mattered—health, economics, housing, forms of government, and so forth. Evidence of that was provided by such pointers as the reports of public libraries, the character of many broadcast talks, and the ready sale of popular editions on subjects of the type just mentioned. That being so, it was only reasonable to believe that thinking men and women would welcome more information, if suitably presented, than was readily available on engineering topics—

*** This and the following contributions were submitted in writing.

problems, methods, projects, and achievements. Knowledge of that kind would do much to foster an understanding of, and support for, those items of the reconstruction programme in which engineering was destined to play a leading part. If, therefore, the engineering profession could, through its Institutions, take a lead in spreading that knowledge, it would be doing far more to oil the wheels of the reconstruction machine than by keeping the knowledge and experience and suggestions of its members to itself and waiting passively for its services to be called upon when the machine was put in motion. Not only could it do so; in the national interest it ought to do so. The help that engineering was in a position to render, in large part, to a State disordered by faulty planning and by war, could be likened to what a skilled physician could do for a disordered body. In both cases it was only fair to the patient that he be told what was wrong with him, how much could be done for him, and the form his treatment should take: and who should tell him but the doctor? Accordingly, with those considerations in view, Mr. Groves submitted that the engineering profession should take the initiative in stimulating public interest in those features of post-war reconstruction which came within its province. He offered the following suggestions:

Publications.—Why not an issue of engineering "Penguins"? Not, of course, under that name, nor in association with the commercial undertaking which had made such a success of the "Penguin" series; the description was used merely to indicate the type of publication which had proved itself acceptable to the man in the street.

No difficulty should be experienced in preparing a number of concise, easily-read, and informative booklets on the engineering aspects of reconstruction. Two or three recent contributions to the Journal, after revision suited to the requirements of the lay reader, might well be included in the series. The Author's Paper was one, whilst another was Professor Inglis' Presidential Address[1], which, although it did not deal with reconstruction schemes, was of great importance to those who would be playing their part in reconstruction during the next twenty or thirty years; there was no question but that numbers of prospective engineering students, and their parents, would read and re-read that Address with interest and profit, not only at the present time but for many years to come. In order to maintain the supply of such publications, a list of suitable titles should be prepared and a scheme of awards for accepted contributions devised.

Broadcasts.—Many broadcast talks were given by doctors, economists, physicists, and other professional men: but how few by engineers, whose work was, to quote the President's words, "now shaping the destiny of civilization." What an anomaly! Most laymen were interested in the work of engineers, and it was certain that suitable talks on the subject

[1] Journal Inst. C.E., vol. 17 (1941–42), p. 1 (Nov. 1941).

could be made a popular and instructive feature of broadcast programmes. Scope existed for useful pioneer work in that direction.

Meetings.—The Institution came into possession, from time to time, of material (such as the Paper) which was of interest and value to a circle far larger than its own membership. It would surely be fitting and desirable that such material, even if discussed at an Institution meeting in the first instance, should also be presented to much wider audiences, with, perhaps, speakers interested in the subject (but not necessarily engineers) invited to take part in the proceedings.

An extension of that suggestion was that a convention should be held to study the engineering aspects of reconstruction. That could hardly fail to be of value, even allowing for the fact that existing circumstances would limit its scope and activities in some degree. Attendance should be invited not only from engineering institutions but also from other societies—for example, The Scapa Society and The National Playing Fields Association—whose members' views would help in a clearer perception of the intricate framework of reconstruction into which the engineer's contribution would require to fit. The proceedings of such a convention would provide the basis of subject-matter for at least one interesting and valuable "Penguin."

Dr. C. S. Myers had asserted in his James Forrest Lecture [1] that engineers were introversive. Perhaps they were; certainly they were as a corporate body. Mr. Groves considered that The Institution, as the parent society of engineers in Great Britain, had a responsibility not only to its members and to the profession as a whole, but also, if only because of the war, to the State. It should surely review its methods and procedure, broaden its contacts, and do all in its power to further the prospects of that new and better social order of which the nation stood in such great need.

Mr. T. H. Longstaff considered that the Author, in applying his vast knowledge and experience to the major problems which would arise in relation to post-war planning and reconstruction, had done a real service not only to The Institution but also to his profession generally. In fact, the subject was so ably dealt with that The Institution might do well to consider passing the Paper on to the appropriate Government Department charged with the duty of formulating post-war development plans.

Next to winning the war, the major problem with which the British nation had to deal was the immediate establishment of a sound, practicable, and economical scheme of post-war reconstruction and development, for its future life and well-being were necessarily dependent thereon. The Author had indicated a basis upon which to build the perfect scheme, although admittedly the actual conditions might not permit the "ideal"

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[1] "Psychology as applied to Engineering", Journal Inst. C.E., vol. 18 (1941–42), p. 295 (Feb. 1942).

to be completely fulfilled. The League of Nations had possessed the most commendable ideals, but owing to the lack of practical facilities with which to establish them its efforts had not prevented a world catastrophe.

It seemed necessary that no time should be lost in taking major decisions on the four items enumerated on p. 237, *ante*. Foresight and sound judgement would be needed in the endeavour to envisage the basic conditions.

For all practical purposes Great Britain might well be considered as one huge industrial concern, which, in the past few years, had been almost entirely transformed for the production of war weapons and materials. During that period it had been subjected to both damage and considerable wear and tear. Meanwhile, other nations with whom a large percentage of its pre-war trade had been carried on, had become highly industrialized and serious inroads had been made into the nation's capital and foreign assets. It would appear that immediately after the cessation of hostilities it would be necessary, without loss of time :—

(1) to adapt, repair, and improve the nation's industrial undertakings to produce 100 per cent. efficiency ;
(2) to provide productive work for every able-bodied man : the national finances would not permit of " carrying passengers " ;
(3) to encourage the personal qualities of thrift, perseverance, and determination to succeed. The members of the community should not be allowed to drift into nothing more than " human machines."
(4) to provide such amenities as business could afford.

A well conceived and carefully prepared scheme was essential and the nation could not afford to lose time in establishing the foundations ; but above all the scheme should be thoroughly practicable, economical, and capable of fulfilment.

Mr. Longstaff feared that failure to adopt that as the post-war outlook would entail grave risk of heading for national bankruptcy.

He considered that the need for a national skeleton plan had been all too obvious for many years past. The organization indicated by the Author would appear to meet the position, and such a Central Department would be able to co-operate with other Government Departments concerned in the establishment of such a plan.

Obviously the invaluable local and practical knowledge possessed by local authorities and their officers, a large number of whom were members of The Institution, was of vital necessity in the preparation and administration of any planning and reconstruction scheme.

It would certainly seem that a case existed for the establishment of a system of regional collaboration. Had the Author considered the possibility of existing county authorities undertaking that duty ? They were already experienced in collaborating with local authorities and in many

instances the staffs of county councils had for some time been engaged in the preparation of planning schemes. An economic advantage was that practically all county councils already had on their staffs officers who possessed the necessary experience together with technical qualifications of high order in engineering, architecture, finance, law, and education.

The Author had stated that secondary communications were regional matters. Presumably county and county borough councils, as the existing leading highway authorities (in consultation with the Ministry of Transport), would be the appropriate bodies to deal therewith. As the planning of road communications would, of necessity, be a subject of major importance in any planning scheme, that might be considered as a further reason why county and county borough councils should become the regional authorities.

Mr. Longstaff suggested for the Author's consideration the provision of a "Supplement" to his very valuable Paper, containing more detailed information in regard to regional and local control.

Mr. A. W. Ward observed that the task foreshadowed in the Paper would be so colossal as almost to overwhelm a nation just emerged from a world war, and it was questionable whether Parliament or people would or could grapple with it, except by stages. Much had been heard about "five-year plans" and it might be that more would be accomplished by proceeding by instalments "on a fixed-time basis"—an expression used several times in the Paper—than would otherwise be the case. The necessity for reorganizing agricultural, industrial, and transport policy and for clearing the land of slum dwellings and building new homes was recognized; one could gauge what was required to make good the damage already caused (but could conjecture only as to what might yet be done) by enemy action; and the mere statement of the case was quite sufficient to indicate that the guiding principles governing the general plan of reconstruction would have to be made with courage, celerity, and vision.

Recently it had been said, in an interesting broadcast, that "democracy must use persuasion in its dealings concerning land." That was a thorny subject, which, because of the traditional British conception of private ownership, had to be approached with some trepidation; but there could be no doubt whatever that it was the rock upon which the whole scheme would be wrecked unless that fundamental subject were dealt with courageously. "Courageously" was not intended to mean outrageously. A clear-sighted policy on the part of landowners generally (including their advisers) would serve the legitimate interests of all concerned infinitely better than would obstruction "to the last ditch." The Author had laid down four "basic principles" (p. 237), and he appeared to have been labouring under a sense of frustration when he wrote the first sentence of the paragraph on "Land Tenure" (p. 239). Something could be gleaned from his change of mood as that paragraph developed, and everyone familiar with the difficulties and almost insuperable delays which were encountered

when the interests of landowners were concerned—and one could imagin how those difficulties would be aggravated when the whole country con stituted the sphere of operations—would heartily endorse his statemen that " . . . the control of land must be definite and not subject t argument and litigation."

A skeleton plan, clearly indicating the broad principles upon which th future development and reconstruction of the country was to be based would clarify the situation immeasurably, stimulate the active interes and support of every section of public opinion, and avoid hasty and wastefu improvization. The Ministry of Works and Buildings had collected, an was still collecting, a mass of valuable information and advice from leader of thought in every profession and business concerned, and it should b possible so to marshal and co-ordinate such information and advice tha a skeleton plan and basic principles could be agreed upon. No sane perso would wish to divert one ounce of effort required for winning the wa but with failure to make physical (as well as political) plans for peace absolute chaos would await the demobilization of vast numbers of me and women.

The Author had made frequent use of such expressions as " loca initiative ", " local interests ", " local authorities ", and had strongl deprecated too rigid a control over Local Planning. Mr. Ward thought tha few, however, would wish to quarrel with the statement made recentl in Parliament :—" We shall encourage planning authorities to group i areas suitable as units. . . . Too many too small units were bein separately planned. In any new or further groupings, local authoriti will be consulted ; I ought not to need to say that."

The number of local authorities might have to be reduced, for it wa doubtless correct to say that there were " too many too small units. That matter might safely be left to Parliament. The task of technical me would be to dovetail local planning and reconstruction into the region and national schemes, and it was that task which would concern the larg body of corporate members of The Institution engaged in local governme service. What had already been accomplished in regional and town pla ning had been mainly the work of those officials. Co-ordination of effo on the part of some planning authorities had, unfortunately, been lackin but, in extenuation, it should be said that there had been no national pl to stir the imagination.

The Government had adopted a five-year plan since hostilities had com menced, in the form of the War Damage Act, which answered the questi as to how the funds would be provided for repairing damage to proper due to enemy action. The power to raise in 5 years a sum equal to ha the Schedule A assessments of property would produce a colossal amou for post-war reconstruction—not less than £150,000,000 on a conservati estimate. In justice to property owners, building operatives, man facturers, engineers, architects, and others, plans should be made

readiness for the time when men could return to their peace-time occupations and reconstruction could begin.

The public conscience had been aroused for action in regard to post-war problems, and had perhaps never been so well informed and expectant. The air was full of educative propaganda, and great satisfaction would be felt if the Council of The Institution were to regard that day's proceedings as inaugurating a new phase in its history, for the part which the engineer should play in that great work (in conjunction, of course, with other professions concerned) had been amply demonstrated.

The Author, in reply, observed that the discussion undoubtedly indicated the wide interest which members of The Institution were taking in the important subject of post-war planning and reconstruction, and it was most encouraging to find that many of the points referred to in the Paper had already provided subjects for considerable thought.

Perhaps the problem which recurred most consistently throughout the discussion was that concerning the constitution and the area of control of detail Planning Authorities; that point had been mentioned by four contributors, who, whilst not disagreeing that some revision of the present position was necessary, had asked for elucidation, whilst Mr. Longstaff had gone so far as to suggest a supplement to the Paper.

The subject was admittedly difficult, but it appeared that unanimity would be found in the suggestion that detail Planning Authorities should operate in an area which was capable of being planned and eventually dealt with, so far as new construction and reconstruction were concerned, as a balanced unit, the chief difficulties being the constitution of the Authority and the area of the unit. It was difficult to define either of those factors in precise terms, but in the Author's opinion the constitution should be democratic and should be local; moreover powers should be more complete than at present, and should embrace not only a complete planning control, but also a much more complete financial control by local authorities.

The area of control was extremely difficult to define in general terms, and in practice would be difficult to define by specific boundaries. There were many factors with which it would be desirable to comply, some of which had been mentioned in the Paper—for example, areas of water-supply and areas bounded by major physical features; but an examination of those desiderata indicated that individually they would require widely varying boundaries. Drainage-areas, for example, might be extended for hundreds of miles—much too far, in fact, for any local cohesion. In dealing with balanced planning, certain areas would be highly urbanized, and others reserved for rural use; whilst the intermediate requirements of agricultural villages, market gardening, and agricultural industries had also to be planned. Each had a bearing upon the others in regard to both human well-being and financial support. A measure of industrial balance between a number of towns would be much

easier if the towns concerned were under a unified control: in some part of Great Britain county areas would hardly be sufficiently large o correctly drawn to achieve that object.

Areas such as the Lake district or the Yorkshire moors need presen no difficulty; they would fall into the category of national reservation and would be subject to special restrictions and control.

The land of Great Britain could never become completely self supporting for its present population—there was not sufficient of it; i had been estimated that approximately 2 acres were required for th complete agricultural needs of one person, and since the area of Grea Britain allowed only a little more than 1 acre per person of population it was useless to attempt to define self-supporting units on a populatio basis.

The excellent planning carried out within county areas in the past would tend to indicate that similar areas would be useful as plannin units in the future; but in the Author's opinion it would be absolutel necessary that the planning control over a county area should includ control also over the area of any contained urban development, includin boroughs and county boroughs. It was probable that such areas woul constitute a very good commencement, although when the plans wer under consideration adjustments would undoubtedly be found to b necessary. There seemed to be no reason why provincial authoritie reconstituted on such a basis should not retain their local interest, whic would be enhanced by a still further localized control by district committee composed of members resident in particular parts of the areas.

The reform of local government was a very complicated subjec involving many matters outside the scope of the engineer; but it was no difficult to lay down definite factors to which a formula could be fitted and the factors could be decided most readily from the defects existing i the present system, all of which—financial, physical, and social—aros from lack of balance.

The psychological aspect of transference of population, mentioned b Sir Frederick Cook, was very important: attachment to "the old home was very complex and was made up, among other things, of friendship a well as familiarity with material things. It would be less upsetting t move a complete community than a single family, and some scheme o those lines might be feasible by transferring a complete industry with a its workers. If, at the same time, the new conditions of living formed vast improvement on the old, the operation would be facilitated. Th important point, however, was that the present generation of people migh have to make certain sacrifices for the well-being of generations to follow who would not be affected by the same psychological inhibitions. In an case, compulsion was undesirable—persuasion based upon real improve ment was the only sound course.

Sir Frederick's remarks concerning transport could not be over-stresse

Communications should form the basis of any national plan, and the formulation of an adequate scheme should be the first task of a Ministry of Planning. The four basic problems referred to, however (despite Mr. Ford's and Mr. Buckley's opinions to the contrary) did not lie within the scope of physical planning; they were matters of major national policy which would govern the formulation of the whole national plan, including communications, and the carrying out of the work; but there was a very clear distinction, for example, between national and international allocation of trade, or the financial economy of a nation, and the planning of the physical use of national space. The planning was governed by the policy decided for the first-named consideration; but unless the term "town and country planning" was to include everything within the scope of human life, physical, social, political, economic—and even spiritual—a distinction must be allowed.

In reply to Mr. Brown, it was intended that a distinction should be drawn between national communications and secondary or local main roads; the latter class of highways was important chiefly to the local or regional traffic, and could well be dealt with locally.

Large towns with a considerable ratable value were undoubtedly able to provide more efficient services of a luxury type—libraries, museums, etc., and such features as a university and an opera house. Moreover the economy of certain large industrial plants required mass labour which could be found only in large towns; but it was probable that all of those advantages could be provided to the ultimate in a community of 250,000 persons, who could live and work under excellent conditions in an area of about 25 square miles. No person in such a town need live at a distance of more than 3 miles from his work or from the open country, provided the surrounding area were properly controlled; any population in excess of that number was unnecessary, and the defects in that respect of the half-dozen largest towns in Great Britain were too well known to need stating. Population tendencies could not be dealt with in the Author's reply; the subject was vitally important and the present tendency was likely to result in a situation of a very dangerous character. Remedies existed, but they were of such a nature that they would be more likely to impose themselves than be voluntarily adopted.

An interesting point had been raised by Mr. Donkin in regard to the cost of burying service mains underground. Under the past and present system of land tenure in Great Britain the owners were in a position to require payment for an easement in respect of any pipes or cables laid under their land—in effect, to make a levy on services to the public; the Author hoped that such anomalies would disappear with a revised system of control.

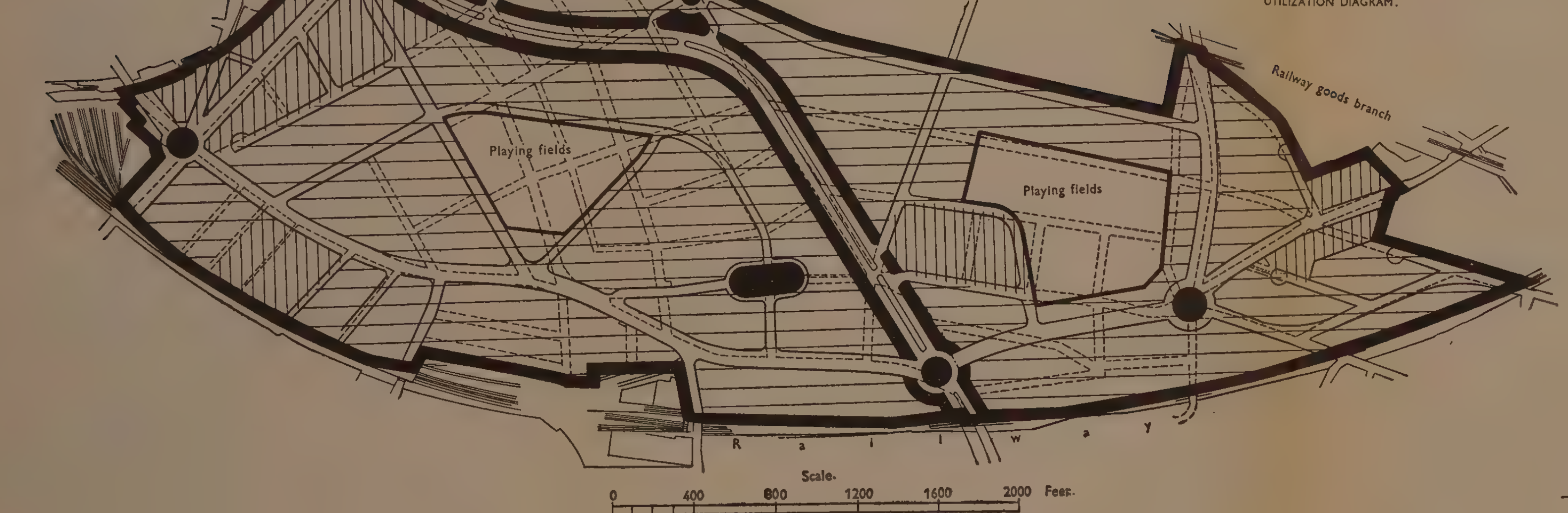
Mr. Buckley had asked specific questions concerning Birmingham, and a reply might be of general interest. Birmingham had an area of more than 50,000 acres (82 square miles). The whole area was planned for

zoning and communications, but the older central parts of the city, about 12,000 acres, were not covered by resolution. Eight individual schemes covered the remainder of the area, five of which were operative schemes, including the first scheme ever approved in Great Britain (1913). About three-quarters of the city had been developed under town planning control, and industry had not been allowed to restart in positions zoned for other purposes, with the important and unfortunate exception of Government-owned industry. Despite that bad example, zoning had operated very effectively.

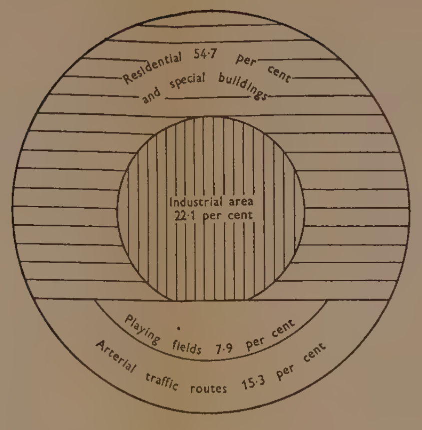
The Author wished to thank the contributors for their many interesting and instructive comments.

There could be no doubt of the responsibilities and opportunities of engineers in the all-important task of reconstruction.

FIGS. 1.

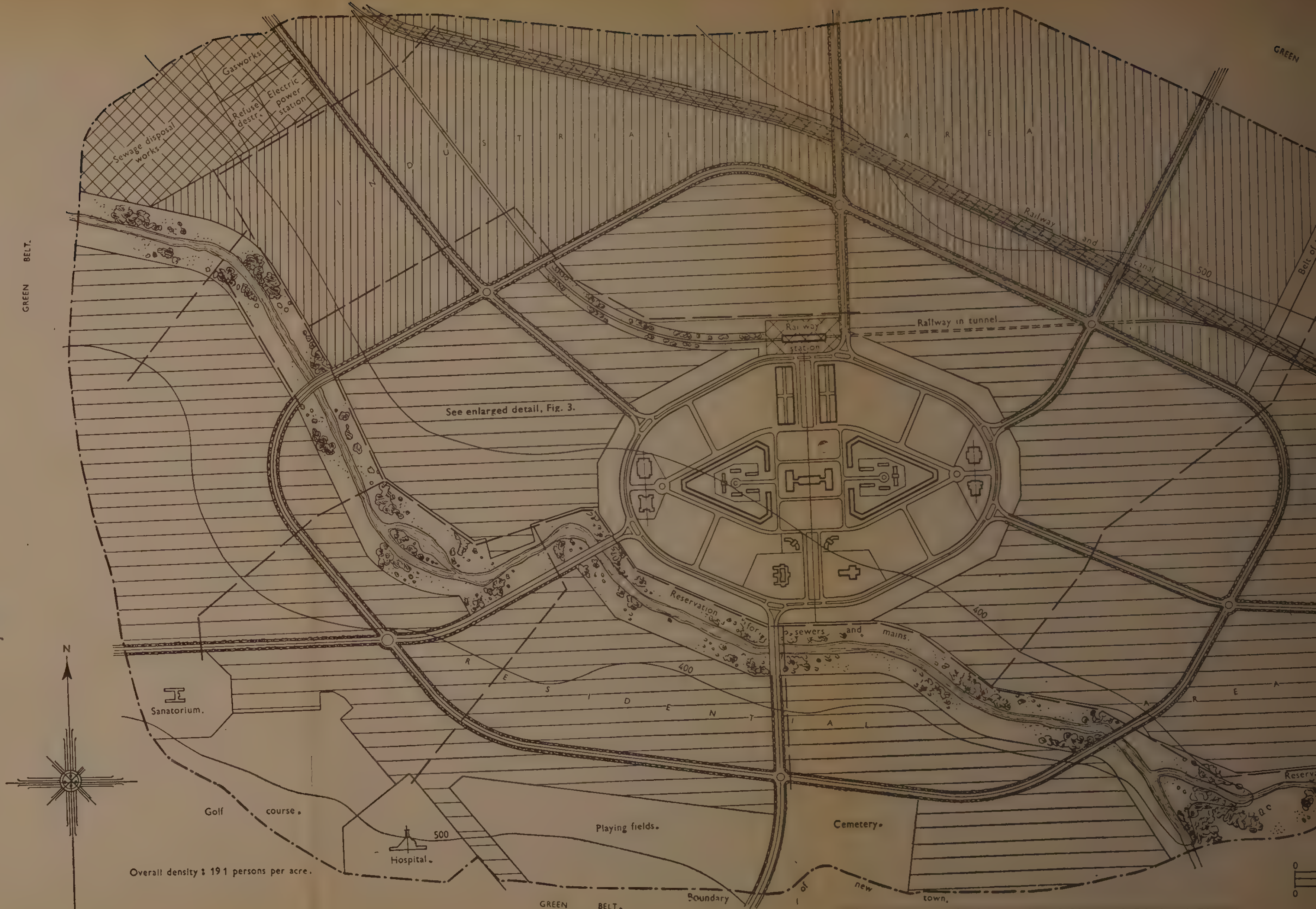


LAYOUT OF AN ACTUAL REDEVELOPMENT AREA.



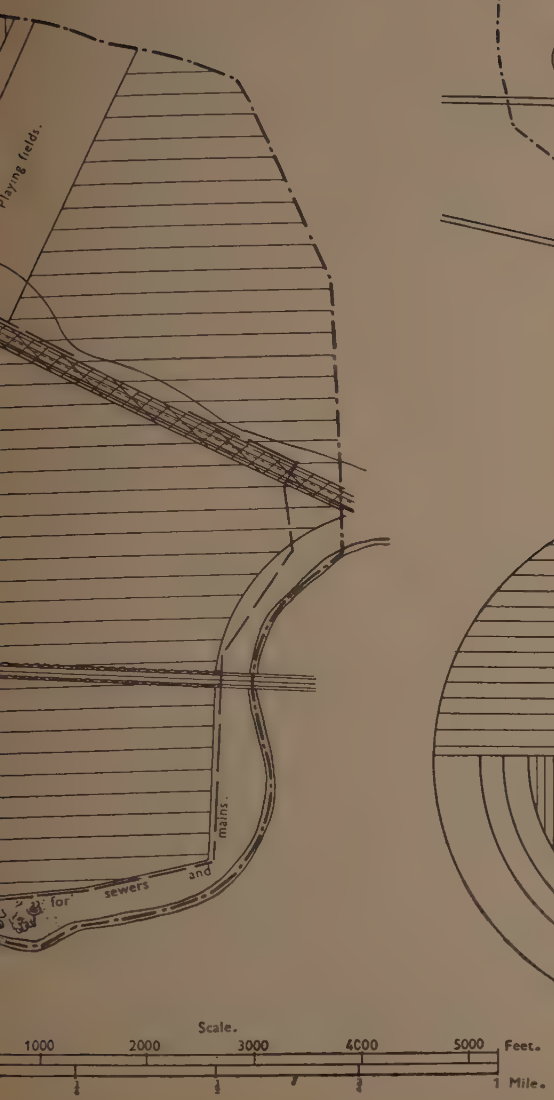
UTILIZATION DIAGRAM.

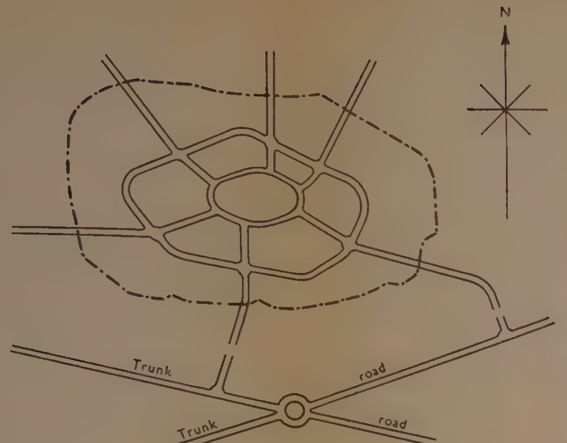
FIGS. 2.



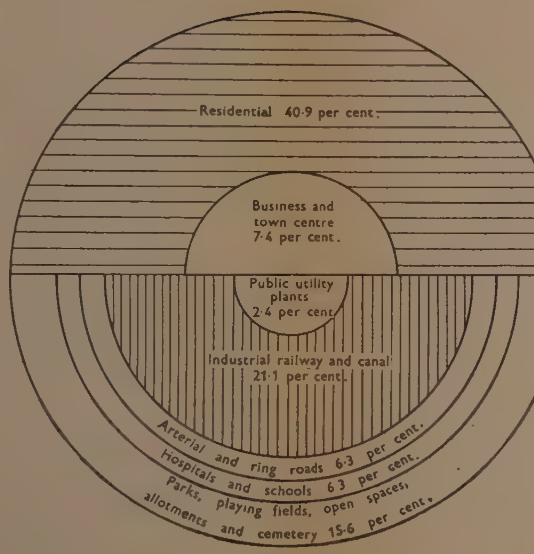
TYPICAL LAYOUT FOR NEW TOWN SHOWING COMMUNICATIONS AND ZONING.

WILLIAM CLOWES & SONS, LIMITED: LONDON.





KEY PLAN
SHOWING RELATIONSHIP OF NEW TOWN
TO MAIN TRAFFIC ROUTES.

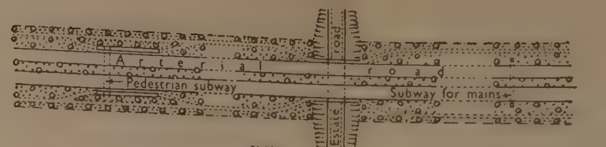


UTILIZATION DIAGRAM.

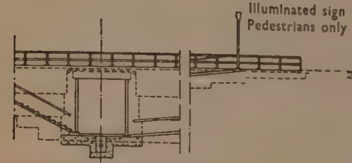
FIG. 3.

LAYOUT OF PORTION OF TOWN SHOWING TYPICAL DEVELOPMENT.

FIGS. 4.

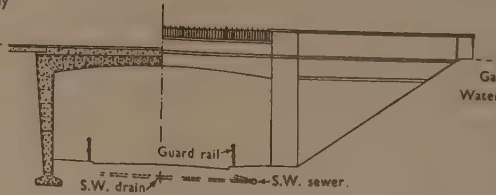


PLAN.



SECTIONAL ELEVATION ON CENTRE LINE OF ACCESS RAMP.

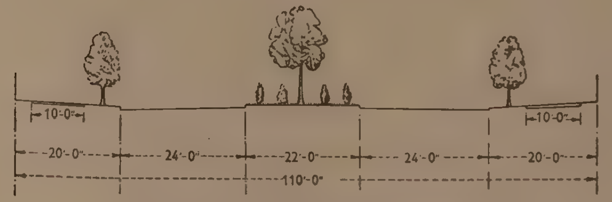
PEDESTRIAN SUBWAY.



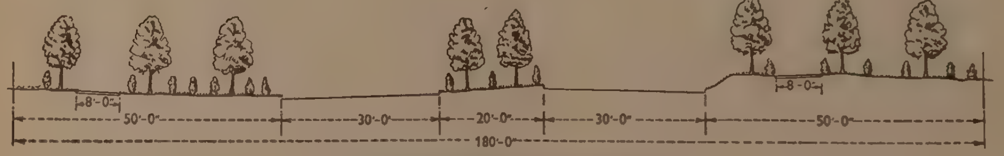
HALF SECTION. HALF ELEVATION
UNDER BRIDGE FOR ESTATE ROAD.

CROSS-SECTION.
SUBWAY FOR MAINS.

SUGGESTED SUBWAYS UNDER ARTERIAL ROAD.



TYPICAL CROSS-SECTION OF INNER RING ROAD.



TYPICAL CROSS-SECTION OF ARTERIAL ROAD
SHOWING PARKWAY TREATMENT.

H. J. B. MANZONI.

Paper No. 5257.

"Vibration of a Thin Vertical Cantilever caused by a Damped Harmonic Disturbance of the Ground."

By Professor MAX BORN, D.Sc., F.R.S.,
and
HUBERT LL. D. PUGH, B.Sc.

INTRODUCTION.

DURING his investigation of the effects of earth waves caused by blasting operations in building structures, described in a Paper, "Vibrations due to Blasting and their Effects on Building Structures",[1] Mr. G. Morris found that any mathematical treatment in which the ground motion was considered as periodic necessarily gave rise to the possibility of resonance between the ground motion and that of the building. He had evaluated the damping of both earth and building structure, but was unable to incorporate the values in solvable equations.

During the course of a legal dispute, in which Mr. Morris and one of the Authors appeared as technical witnesses, this difficulty was explained, and the discussion of the problem led to the investigation of the vibrations of a vertical elastic cantilever under the action of a damped harmonic disturbance of the ground. The purpose of this Paper is to describe the investigation.

(1) DIFFERENTIAL EQUATION AND BOUNDARY CONDITIONS.

A Cartesian co-ordinate system is used, the origin 0 of which coincides with the base of the cantilever, whilst its x-axis is vertically upwards. The motion of the earth's surface at 0 may be represented by

$$y = f(t) = He^{-\kappa t} \sin \omega t, \quad t > 0 \quad . \quad . \quad . \quad . \quad (1.1)$$

It is sufficient to consider the deflexions of the points of the cantilever parallel to the disturbance, $y(x, t)$. Using a dot for the derivative with respect to t and a dash for that with respect to x,

$$\dot{y} = \frac{\partial y}{\partial t}, \quad y' = \frac{\partial y}{\partial x}; \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.2)$$

[1] Not yet published.

the differential equation for the motion of the cantilever considered as a[n] elastic beam is

$$\ddot{y} + \frac{Ek^2}{\rho} y'''' = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.3)$$

where ρ denotes the density, E denotes Young's modulus, and k denote[s] the radius of gyration (square root of moment of inertia divided by th[e] mass) of the cross-section.

The bending moment is represented by

$$M = EAk^2 y'', \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.4)$$

where A denotes the area of the cross-section.

Assuming the lower end, at $x = 0$, "clamped" in the earth, the uppe[r] end, at $x = l$, "free", and the cantilever at rest at the moment $t =$ [0] when the disturbance reaches it; the boundary and initial conditions are

$$\begin{aligned} &y(0, t) = f(t), \quad y'(0, t) = 0; \quad y(x, 0) = 0, \\ &y''(l, t) = 0, \quad y'''(l, t) = 0; \quad \dot{y}(x, 0) = 0, \quad . \quad . \quad . \quad (1.5) \end{aligned}$$

where $f(t)$ is the function given by equation (1.1).

It is convenient to introduce instead of $f(t)$ the function

$$g(t) = He^{i\gamma t} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.6)$$

where

$$\gamma = \omega + i\kappa; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.7)$$

then

$$f(t) = \frac{1}{2i}[g(t) - g^*(t)], \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.8)$$

where the asterisk indicates the complex conjugate expression. Accord[-]ingly the solution is split into

$$y = \frac{1}{2i}(u - u^*); \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.9)$$

then $u(x, t)$ satisfies the same differential equation (1.3), but the boundar[y] and initial conditions are represented by

$$\begin{aligned} &u(0, t) = g(t), \quad u'(0, t) = 0; \quad u(x, 0) = 0, \\ &u''(l, t) = 0, \quad u'''(l, t) = 0; \quad \dot{u}(x, 0) = 0. \quad . \quad . \quad (1.10) \end{aligned}$$

A particular solution, synchronous with the perturbing force, is obtaine[d] by taking

$$u_s(x, t) = v(x)e^{i\gamma t} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.11)$$

where $v(x)$ has to satisfy the ordinary differential equation

$$\frac{Ek^2}{\rho} v'''' - \gamma^2 v = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.12)$$

with the boundary conditions

$$v(0) = H, \quad v'(0) = 0,$$
$$v''(l) = 0, \quad v'''(l) = 0. \quad \quad (1.13)$$

u_s does not satisfy the initial conditions. A solution of the homogeneous problem, that is, a function u_f representing a free vibration, must be added, and the integration constants chosen in such a way that the initial conditions are satisfied, as in section (3), page 286, *post.*

(2) Synchronous Solution.

The function

$$v = e^{\lambda x/l} \quad \quad (2.1)$$

is a solution of equation (1.12) if λ satisfies

$$\omega_0^2\lambda^4 - \gamma^2 = 0 \quad \quad (2.2)$$

where

$$\omega_0 = \frac{1}{l^2}\sqrt{\frac{Ek^2}{\rho}} \quad \quad (2.3)$$

is a constant of the dimensions of a frequency, characteristic of the cantilever. Introducing the quantity

$$\lambda_0 = \sqrt{\frac{\gamma}{\omega_0}}, \quad \quad (2.4)$$

the four roots of equation (2.2) are

$$\lambda_1 = \lambda_0\,; \quad \lambda_2 = -\lambda_0\,; \quad \lambda_3 = i\lambda_0\,; \quad \lambda_4 = -i\lambda_0\,. \quad \quad (2.5)$$

Combining the four solutions $exp(\lambda_k x/l)$, $(k = 1, 2, 3, 4)$, in pairs, the general solution can be written,

$$v(x) = A\cos\frac{\lambda_0 x}{l} + B\sin\frac{\lambda_0 x}{l} + C\cosh\frac{\lambda_0 x}{l} + D\sinh\frac{\lambda_0 x}{l}. \quad \quad (2.6)$$

The boundary conditions (equation 1.13) lead to

$$\left.\begin{aligned} A + C &= H\,; \\ B + D &= 0\,; \\ -A\cos\lambda_0 - B\sin\lambda_0 + C\cosh\lambda_0 + D\sinh\lambda_0 &= 0\,; \\ A\sin\lambda_0 - B\cos\lambda_0 + C\sinh\lambda_0 + D\cosh\lambda_0 &= 0. \end{aligned}\right\} \quad (2.7)$$

The solutions of these equations can be written

$$\left.\begin{aligned} A &= \tfrac{1}{2}H\left(1 - \frac{\sin\lambda_0\sinh\lambda_0}{1 + \cos\lambda_0\cosh\lambda_0}\right), \\ B = -D &= \tfrac{1}{2}H\,\frac{\cos\lambda_0\sinh\lambda_0 + \sin\lambda_0\cosh\lambda_0}{1 + \cos\lambda_0\cosh\lambda_0}, \\ C &= \tfrac{1}{2}H\left(1 + \frac{\sin\lambda_0\sinh\lambda_0}{1 + \cos\lambda_0\cosh\lambda_0}\right). \end{aligned}\right\} \quad (2.8)$$

As λ_0 is complex, these constants, and therefore $v(x)$, are complex.

$$
\begin{aligned}
v &= F_{\mathrm{R}}(x) + iF_{\mathrm{I}}(x) \\
&= \tfrac{1}{2}H\left[\left(\cos\frac{\lambda_0 x}{l} + \cosh\frac{\lambda_0 x}{l}\right)\right. \\
&\quad + \frac{\sin\lambda_0 \sinh\lambda_0}{1+\cos\lambda_0\cosh\lambda_0}\left(\cosh\frac{\lambda_0 x}{l} - \cos\frac{\lambda_0 x}{l}\right) \\
&\quad \left. + \frac{\cos\lambda_0\sinh\lambda_0 + \sin\lambda_0\cosh\lambda_0}{1+\cos\lambda_0\cosh\lambda_0}\left(\sin\frac{\lambda_0 x}{l} - \sinh\frac{\lambda_0 x}{l}\right)\right]. \quad (2.9)
\end{aligned}
$$

The synchronous part of the solution is now given by equations (1.7), (1.9), and (1.11), in the form

$$
\begin{aligned}
y_s(x, t) &= \frac{1}{2i}[v(x)e^{i\gamma t} - v^*(x)e^{-i\gamma^* t}] \\
&= e^{-\kappa t}[F_{\mathrm{I}}(x)\cos\omega t + F_{\mathrm{R}}(x)\sin\omega t] \quad . \quad . \quad (2.10)
\end{aligned}
$$

Writing

$$\lambda_0 = \mu + i\nu, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2.11)$$

from equation (2.4),

$$\gamma = \omega + i\kappa = \omega_0\lambda_0^2 = \omega_0(\mu + i\nu)^2 = \omega_0[(\mu^2 - \nu^2) + 2i\mu\nu]$$

is obtained; hence

$$\mu^2 - \nu^2 = \frac{\omega}{\omega_0}; \quad 2\mu\nu = \frac{\kappa}{\omega_0},$$

Solving with respect to μ, ν,

$$
\left.
\begin{aligned}
\mu^2 &= \frac{\omega}{\omega_0}\frac{1}{2}\left(\sqrt{1+\left(\frac{\kappa}{\omega}\right)^2} + 1\right) \\
\nu^2 &= \frac{\omega}{\omega_0}\frac{1}{2}\left(\sqrt{1+\left(\frac{\kappa}{\omega}\right)^2} - 1\right)
\end{aligned}
\right\} \quad . \quad . \quad . \quad . \quad . \quad (2.12)
$$

F_{I} and F_{R} are obtained from equation (2.9) by introducing $\lambda_0 = \mu + i\nu$ and splitting into real and imaginary parts. One of the coefficients namely,

$$\frac{\sin\lambda_0\sinh\lambda_0}{1+\cos\lambda_0\cosh\lambda_0} = \frac{\sin\lambda_0\sinh\lambda_0(1+\cos\lambda_0^*\cosh\lambda_0^*)}{|1+\cos\lambda_0\cosh\lambda_0|^2} \quad . \quad (2.13)$$

is considered in detail.

The following relations are used:

$$
\left.
\begin{aligned}
\cos\lambda_0 &= \cos(\mu + i\nu) = \cos\mu\cosh\nu - i\sin\mu\sinh\nu, \\
\cosh\lambda_0 &= \cosh(\mu + i\nu) = \cosh\mu\cos\nu + i\sinh\mu\sin\nu, \\
\sin\lambda_0 &= \sin(\mu + i\nu) = \sin\mu\cosh\nu + i\cos\mu\sinh\nu, \\
\sinh\lambda_0 &= \sinh(\mu + i\nu) = \sinh\mu\cos\nu + i\cosh\mu\sin\nu.
\end{aligned}
\right\} \quad . \quad . \quad (2.14)
$$

Then

$$\begin{aligned}\Delta &= |1 + \cos\lambda_0 \cosh\lambda_0|^2 \\ &= 1 + \cos\lambda_0 \cos\lambda_0 + \cos\lambda_0{}^* \cosh\lambda_0{}^* + \cos\lambda_0 \cos\lambda_0{}^* \cosh\lambda_0 \cosh\lambda_0{}^* \\ &= 1 + 2(\sin\mu \sin\nu \sinh\mu \sinh\nu + \cos\mu \cos\nu \cosh\mu \cosh\nu) \\ &\quad + (\cos^2\mu \cosh^2\nu + \sin^2\mu \sinh^2\nu) \,.\, (\cosh^2\mu \cos^2\nu + \sinh^2\mu \sin^2\nu).\end{aligned}$$

The last product can be written

$$\begin{aligned}(\cosh^2\nu - \sin^2\mu) \,.\, (\cosh^2\mu - \sin^2\nu) &= \cosh^2\mu \cosh^2\nu - \sin^2\mu(1 + \sinh^2\mu) \\ &\quad - \sin^2\nu(1 + \sinh^2\nu) + (1 - \cos^2\mu)(1 - \cos^2\nu) \\ &= \cosh^2\mu \cosh^2\nu + \cos^2\mu \cos^2\nu - \sin^2\mu \sinh^2\mu - \sin^2\nu \sinh^2\nu - 1.\end{aligned}$$

Hence

$$\begin{aligned}\Delta &= |1 + \cos\lambda_0 \cosh\lambda_0|^2 \\ &= (\cosh\mu \cosh\nu + \cos\mu \cos\nu)^2 - (\sin\mu \sinh\mu - \sin\nu \sinh\nu)^2. \quad (2.15)\end{aligned}$$

In a similar way,

$$\begin{aligned}\sin\lambda_0 \sinh\lambda_0(1 + \cos\lambda_0{}^* \cosh\lambda_0{}^*) &= (\cos\mu \cosh\mu + \cos\nu \cosh\nu) \,.\, (\sin\mu \sinh\mu - \sin\nu \sinh\nu) \\ &\quad + i(\cosh\mu \cosh\nu + \cos\mu \cos\nu) \,.\, (\sinh\mu \sinh\nu + \sin\mu \sin\nu) \quad (2.16)\end{aligned}$$

is obtained.

Substituting equations (2.15) and (2.16) in (2.13),

$$\frac{\sin\lambda_0 \sinh\lambda_0}{1 + \cos\lambda_0 \cosh\lambda_0} = a + ib, \quad . \quad . \quad . \quad . \quad . \quad (2.17)$$

with

$$\left.\begin{aligned}a &= \frac{1}{\Delta}(\cos\mu \cosh\mu + \cos\nu \cosh\nu) \,.\, (\sin\mu \sinh\mu - \sin\nu \sinh\nu), \\ b &= \frac{1}{\Delta}(\cosh\mu \cosh\nu + \cos\mu \cos\nu) \,.\, (\sinh\mu \sinh\nu + \sin\mu \sin\nu).\end{aligned}\right\} \quad (2.18)$$

In the same way :

$$\frac{\cos\lambda_0 \sinh\lambda_0 + \sin\lambda_0 \cosh\lambda_0}{1 + \cos\lambda_0 \cosh\lambda_0} = c + id \quad . \quad . \quad . \quad (2.19)$$

with

$$\left.\begin{aligned}c &= \frac{1}{\Delta}\{(\cos\mu \cosh\mu + \cos\nu \cosh\nu) \,.\, (\sin\mu \cosh\mu + \cos\mu \sinh\mu) \\ &\quad + (\cosh\mu \sinh\nu - \cos\mu \sin\nu) \,.\, (\sinh\mu \sinh\nu + \sin\mu \sin\nu)\}, \\ d &= \frac{1}{\Delta}\{(\cos\mu \cosh\mu + \cos\nu \cosh\nu) \,.\, (\sin\nu \cosh\nu + \cos\nu \sinh\nu) \\ &\quad + (\sinh\mu \cosh\nu - \sin\mu \cos\nu) \,.\, (\sinh\nu \sinh\mu + \sin\mu \sin\nu)\}.\end{aligned}\right\} \quad (2.20)$$

Substituting equations (2.17) and (2.19) in (2.9), the following expression is obtained with the help of equation (2.14):

$$
\begin{aligned}
F_{\mathrm{R}}(x) + iF_{\mathrm{I}}(x) = \tfrac{1}{2}H\Bigg[&\left(\cos\frac{\mu x}{l}\cosh\frac{\nu x}{l} + \cosh\frac{\mu x}{l}\cos\frac{\nu x}{l}\right) \\
&+ i\left(\sinh\frac{\mu x}{l}\sin\frac{\nu x}{l} - \sin\frac{\mu x}{l}\sinh\frac{\nu x}{l}\right) \\
&+ (a+ib)\left\{\left(\cosh\frac{\mu x}{l}\cos\frac{\nu x}{l} - \cos\frac{\mu x}{l}\cosh\frac{\nu x}{l}\right)\right. \\
&\left.+ i\left(\sinh\frac{\mu x}{l}\sin\frac{\nu x}{l} + \sin\frac{\mu x}{l}\sinh\frac{\nu x}{l}\right)\right\} \\
&+ (c+id)\left\{\left(\sin\frac{\mu x}{l}\cosh\frac{\nu x}{l} - \sinh\frac{\mu x}{l}\cos\frac{\nu x}{l}\right)\right. \\
&\left.+ i\left(\cos\frac{\mu x}{l}\sinh\frac{\nu x}{l} - \cosh\frac{\mu x}{l}\sin\frac{\nu x}{l}\right)\right\}\Bigg] \quad . \quad . \quad (2.21)
\end{aligned}
$$

Splitting this expression into real and imaginary parts,

$$
\left.
\begin{aligned}
F_{\mathrm{R}}(x) = \tfrac{1}{2}H\Bigg[&\left(\cos\frac{\mu x}{l}\cosh\frac{\nu x}{l} + \cosh\frac{\mu x}{l}\cos\frac{\nu x}{l}\right) \\
&+ a\left(\cosh\frac{\mu x}{l}\cos\frac{\nu x}{l} - \cos\frac{\mu x}{l}\cosh\frac{\nu x}{l}\right) \\
&- b\left(\sinh\frac{\mu x}{l}\sin\frac{\nu x}{l} + \sin\frac{\mu x}{l}\sinh\frac{\nu x}{l}\right) \\
&+ c\left(\sin\frac{\mu x}{l}\cosh\frac{\nu x}{l} - \sinh\frac{\mu x}{l}\cos\frac{\nu x}{l}\right) \\
&- d\left(\cos\frac{\mu x}{l}\sinh\frac{\nu x}{l} - \cosh\frac{\mu x}{l}\sin\frac{\nu x}{l}\right)\Bigg], \\
F_{\mathrm{I}}(x) = \tfrac{1}{2}H\Bigg[&\left(\sinh\frac{\mu x}{l}\sin\frac{\nu x}{l} - \sin\frac{\mu x}{l}\sinh\frac{\nu x}{l}\right) \\
&+ a\left(\sinh\frac{\mu x}{l}\sin\frac{\nu x}{l} + \sin\frac{\mu x}{l}\sinh\frac{\nu x}{l}\right) \\
&+ b\left(\cosh\frac{\mu x}{l}\cos\frac{\nu x}{l} - \cos\frac{\mu x}{l}\cosh\frac{\nu x}{l}\right) \\
&+ c\left(\cos\frac{\mu x}{l}\sinh\frac{\nu x}{l} - \cosh\frac{\mu x}{l}\sin\frac{\nu x}{l}\right) \\
&+ d\left(\sin\frac{\mu x}{l}\cosh\frac{\nu x}{l} - \sinh\frac{\mu x}{l}\cos\frac{\nu x}{l}\right)\Bigg].
\end{aligned}
\right\} \quad . \quad . \quad (2.22)
$$

These expressions, substituted in equation (2.10), give the synchronous part of the solution.

In the following considerations, only the value of the bending moment at $x = 0$ is needed, which is proportional to $y_s''(o, t)$ (equation 2.9),

$$v''(0) = F_R''(0) + iF_I''(0) = H \frac{\lambda_0^2}{l^2} \frac{\sin \lambda_0 \sinh \lambda_0}{1 + \cos \lambda_0 \cosh \lambda_0},$$

or with equations (2.3), (2.4), and (2.17),

$$v''(0) = H \frac{\omega + i\kappa}{l^2 \omega_0}(a + ib),$$

and

$$\left.\begin{aligned} F_R''(0) &= \frac{H}{l^2\omega_0}(\omega a - \kappa b), \\ F_I''(0) &= \frac{H}{l^2\omega_0}(\omega b + \kappa a) \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2.23)$$

The synchronous part of the bending moment (equation 1.4) is therefore

$$\begin{aligned} M_s &= \frac{EAk^2H}{l^2\omega_0} e^{-\kappa t}[(\omega a - \kappa b) \sin \omega t + (\omega b + \kappa a) \cos \omega t] \\ &= \frac{EAk^2H}{l^2} \sqrt{\left(\frac{\omega}{\omega_0}\right)^2 + \left(\frac{k}{\omega_0}\right)^2} \sqrt{a^2 + b^2}\, e^{-\kappa t} \sin (\omega t + \epsilon), \quad (2.24) \end{aligned}$$

where

$$\epsilon = \text{arc} \tan \frac{\omega b + \kappa a}{\omega a - \kappa b} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2.25)$$

The second expression of equation (2.24) shows that the bending moment at the bottom of the cantilever follows the same time law as the perturbing motion, with a phase difference ϵ. The factor

$$\sqrt{\left(\frac{\omega}{\omega_0}\right)^2 + \left(\frac{\kappa}{\omega_0}\right)^2}$$

can also be expressed by μ and ν. From equation (2.12),

$$\sqrt{\left(\frac{\omega}{\omega_0}\right)^2 + \left(\frac{\kappa}{\omega_0}\right)^2} = \mu^2 + \nu^2. \quad . \quad . \quad . \quad . \quad . \quad (2.26)$$

(3) Complementary Free Vibration.

The free vibrations of a clamped bar have been determined by Lord Rayleigh.[1]

They are represented by

$$y_j = f_j(x) \sin \omega_j t, \qquad \omega_j = \omega_0 \mu_j^2, \quad . \quad . \quad . \quad . \quad (3.1)$$

where μ_j is a root of the transcendental equation

$$\cos \mu_j \cosh \mu_j + 1 = 0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3.2)$$

[1] "Theory of Sound," vol. I, section 173, p. 276.

The functions $f_j(x)$ are orthogonal; assuming them to be normalized

$$\int_0^l f_j(x) f_{j'}(x) dx = \delta_{jj'} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3.3)$$

The determination of the normalizing factor from Rayleigh's expression [1] for $f_j(x)$ is an elementary, but lengthy calculation; the result is:

$$f_j(x) = \frac{1}{\sqrt{l}}\left\{\cosh\frac{\mu_j x}{l} - \cos\frac{\mu_j x}{l} - g_j\left(\sinh\frac{\mu_j x}{l} - \sin\frac{\mu_j x}{l}\right)\right\} \quad . \quad (3.4)$$

with

$$g_j = \frac{\cos\mu_j + \cosh\mu_j}{\sin\mu_j + \sinh\mu_j} = \left\{\begin{array}{l} -\tan\frac{\mu_j}{2} \text{ for } j \text{ even,} \\ \\ \cos\frac{\mu_j}{2} \text{ for } j \text{ odd.} \end{array}\right\} \quad . \quad . \quad (3.5)$$

The general free vibration is the superposition

$$y_f = \sqrt{l}\sum_j f_j(x)(A_j \sin\omega_j t + B_j \cos\omega_j t), \quad . \quad . \quad . \quad (3.6)$$

and the complete solution of the problem of forced vibrations has the form

$$y = y_s + y_f = e^{-\kappa t}[F_{\mathrm{R}}(x)\sin\omega t + F_{\mathrm{I}}(x)\cos\omega t]$$
$$+ \sqrt{l}\sum_j f_j(x)(A_j \sin\omega_j t + B_j \cos\omega_j t) \quad . \quad . \quad . \quad (3.7)$$

if the constants A_j, B_j are determined in such a way that

$$y(x, 0) = 0, \quad \dot{y}(x, 0) = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (3.8)$$

This gives the conditions

$$\left.\begin{array}{r} F_{\mathrm{I}}(x) + \sqrt{l}\sum_j B_j f_j(x) = 0 \\ {[\omega F_{\mathrm{R}}(x) - \kappa F_{\mathrm{I}}(x)]} + \sqrt{l}\sum_j A_j\omega_j f_j(x) = 0 \end{array}\right\} \quad . \quad . \quad (3.9)$$

Since the functions $f_j(x)$ form an ortho-normal system,

$$\left.\begin{array}{l} B_j = -\frac{1}{\sqrt{l}}\int_0^l F_{\mathrm{I}}(x) f_j(x) dx, \\ \omega_j A_j = -\frac{1}{\sqrt{l}}\int_0^l \{\omega F_{\mathrm{R}}(x) - \kappa F_{\mathrm{I}}(x)\} f_j(x) dx. \end{array}\right\} \quad . \quad . \quad (3.10)$$

---

[1] Rayleigh gives two solutions; the second is obtained from equation (3.4) by replacing g_j by

$$g'_j = \frac{\sinh\mu_j - \sin\mu_j}{\cos\mu_j + \cosh\mu_j};$$

but this solution is identical with the first; for, with equation (3.2),

$$\frac{g_j}{g'_j} = \frac{(\cos\mu_j + \cosh\mu_j)^2}{\sinh^2\mu_j - \sin^2\mu_j} = \frac{1 - \sin^2\mu_j + 1 + \sinh^2\mu_j + 2\cos\mu_j\cosh\mu_j}{\sinh^2\mu_j - \sin^2\mu_j} = 1.$$

It is easy to calculate

$$C_j = \frac{1}{\sqrt{l}}\int_0^l \{F_{\mathrm{R}}(x) + iF_{\mathrm{I}}(x)\}f_j(x)dx = \frac{1}{\sqrt{l}}\int_0^l v(x)f_j(x)dx\,; \quad . \quad (3.11)$$

then

$$\left.\begin{aligned} \omega_j A_j &= -\{\omega R C_j - kTC_j\}, \\ B_j &= -\,TC_j \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (3.12)$$

Using equations (2.9) for $v(x)$ and (3.4) for $f_j(x)$, the integration (3.11) can be performed, and after some straightforward, but lengthy, calculation the following remarkably simple result is obtained :

$$C_j = 2H\frac{g_j}{\mu_j}\frac{1}{1-\left(\dfrac{\lambda_0}{\mu_j}\right)^4} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3.13)$$

Now from equations (2.4), (2.11), and (3.1),

$$\frac{\lambda_0{}^4}{\mu_j{}^4} = \left(\frac{\omega + i\kappa}{\omega_j}\right)^2 = \frac{\omega^2 - \kappa^2}{\omega_j{}^2} + i\frac{2\omega\kappa}{\omega_j{}^2}\,; \quad . \quad . \quad . \quad (3.14)$$

therefore

$$C_j = 2H\frac{g_j}{\mu_j}\frac{\left(1 - \dfrac{\omega^2-\kappa^2}{\omega_j{}^2}\right) + i\dfrac{2\omega\kappa}{\omega_j{}^2}}{\left(1-\dfrac{\omega^2-\kappa^2}{\omega_j{}^2}\right)^2 + \dfrac{4\omega^2\kappa^2}{\omega_j{}^4}} \quad . \quad . \quad . \quad (3.15)$$

By substituting this in equation (3.12),

$$\left.\begin{aligned} A_j &= -\,2H\frac{g_j}{\mu_j}\frac{\omega}{\omega_j}\frac{1 - \dfrac{\omega^2+\kappa^2}{\omega_j{}^2}}{\left(1-\dfrac{\omega^2-\kappa^2}{\omega_j{}^2}\right)^2 + \dfrac{4\omega^2\kappa^2}{\omega_j{}^4}} \\ B_j &= -\,2H\frac{g_j}{\mu_j}\frac{\omega}{\omega_j}\frac{2\dfrac{\kappa}{\omega_j}}{\left(1-\dfrac{\omega^2-\kappa^2}{\omega_j{}^2}\right)^2 + \dfrac{4\omega^2\kappa^2}{\omega_j{}^4}} \end{aligned}\right\} \quad . \quad . \quad (3.16)$$

is obtained.

The contribution of the complementary free vibration to the bending moment at $x = 0$ is :

$$\begin{aligned} M_f &= EAk^2\sqrt{l}\sum_j f_j''(0)(A_j \sin\omega_j t + B_j \cos\omega_j t) \\ &= \frac{EAk^2}{l^2}\sum_j 2\mu_j{}^2(A_j \sin\omega_j t + B_j\cos\omega_j t). \end{aligned} \quad . \quad . \quad (3.17)$$

This can be written

$$M_f = -\frac{EAk^2H}{l^2}4\sum_j g_j\mu_j \frac{\dfrac{\omega}{\omega_j}}{\sqrt{\left(1-\dfrac{\omega^2-\kappa^2}{\omega_j{}^2}\right)^2 + \dfrac{4\omega^2\kappa^2}{\omega_j{}^4}}}\sin(\omega_j t + \epsilon_j), \quad . \quad (3.18)$$

with
$$\epsilon_j = \arc\tan \frac{2\dfrac{\kappa}{\omega_j}}{1 - \dfrac{\omega^2 + \kappa^2}{\omega_j^2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3.19)$$

(4) The Total Bending Moment at Ground Level.

The total bending moment at $x = 0$ is calculated by adding M_s (equation 2.24) and M_f (equation 3.18).

If the cantilever were a rigid cylinder of mass $m = \rho Al$, undamped vibrations of the ground with the frequency ω would result in a movement equivalent to that produced by a force $m\omega^2 H$ acting at the centre $x = l/2$; the corresponding static moment is

$$M_0 = \frac{l}{2} m\omega^2 H = \frac{l^2}{2} \rho\omega^2 AH \quad . \quad . \quad . \quad . \quad . \quad . \quad (4.1)$$

A resonance factor β, which represents the elastic properties of the cantilever, is defined by

$$\beta = \frac{M}{M_0} = \frac{M_s + M_f}{M_0} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4.2)$$

The constant factor in M_s and M_f, divided by M_0, gives

$$\frac{EAk^2H}{l^2 M_0} = \frac{2Ek^2}{l^4 \omega^2 \rho} = \frac{2\omega_0^2}{\omega^2},$$

in virtue of equation (2.3). Hence is obtained

$$\beta = 2\frac{\omega_0^2}{\omega^2} \left\{ \sqrt{\left(\frac{\omega}{\omega_0}\right)^2 + \left(\frac{\kappa}{\omega_0}\right)^2} \sqrt{a^2 + b^2} e^{-\kappa t} \sin(\omega t + \epsilon) \right.$$
$$\left. + 4 \sum_j g_j \mu_j \frac{\omega/\omega_j}{\sqrt{\left(1 - \dfrac{\omega^2 - \kappa^2}{\omega_j^2}\right)^2 + 4\dfrac{\omega^2\kappa^2}{\omega_j^4}}} \sin(\omega_j t + \epsilon_j) \right\} \quad . \quad (4.3)$$

This formula permits a simple interpretation. The first term represent the immediate effect of the disturbance upon the cantilever, which decay exponentially in the same way as the disturbance. The series represent undamped forced vibrations with the characteristic periods ω_j excite during the decaying action of the disturbance. After the first term ha shrunk to an insignificant fraction the free vibrations alone remain. I actual fact the latter will also be damped by the internal friction of th cantilever and the air resistance; but these forces have been neglecte It is therefore sufficient to consider the single terms corresponding to th proper vibrations. Writing

$$\beta \to \beta_f = \sum_j \beta_j \sin(\omega_j t + \epsilon_j), \quad . \quad . \quad . \quad . \quad . \quad (4.4)$$

then

$$\beta_j = \alpha_j \phi\left(\frac{\omega^2 - \omega_j^2}{\omega_j^2}, \frac{\kappa^2}{\omega_j^2}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4.5)$$

where

$$\alpha_j = 8g_j\mu_j\left(\frac{\omega_0}{\omega_j}\right)^2 = 8\frac{g_j}{\mu_j^3}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4.6)$$

$$\phi(z, \zeta) = \frac{1}{\sqrt{(1+z) \cdot [(z+\zeta)^2 + 4\zeta]}} \quad . \quad . \quad . \quad . \quad . \quad (4.7)$$

The function $\phi(z, \zeta)$ represents, for a given ζ, the form of the resonance curve which is the same for all frequencies ω_j if ω_j is taken as the unit of ω and κ, according to equation (4.5). If the neighbourhood of the resonance point is considered and z in the factor $1 + z$ is neglected, then, approximately,

$$\phi(z, \zeta) = \frac{1}{\sqrt{(z+\zeta)^2 + 4\zeta}}; \quad . \quad . \quad . \quad . \quad . \quad . \quad (4.8)$$

this shows that ϕ has a maximum at $z_0 = -\zeta$, or $\omega = \sqrt{\omega_j^2 - \kappa^2}$. The maximum value of ϕ is

$$\phi_{\max} = \frac{1}{2\sqrt{\zeta}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4.9)$$

The values of z where ϕ has fallen to $\frac{1}{n}$ of its maximum are given by

$$z - z_0 = \pm 2\sqrt{\zeta} \cdot \sqrt{n^2 - 1};$$

hence the width of the region of resonance, defined by $n = 2$, ("half width") is

$$\Delta z = 4\sqrt{3\zeta} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4.10)$$

and

$$\left.\begin{aligned} (\beta_j)_{\max} &= 4\frac{g_j}{\mu_j^3}\frac{\omega_j}{\kappa} \\ \frac{\Delta\omega}{\omega_j} &= 2\sqrt{3}\frac{\kappa}{\omega} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4.11)$$

The logarithmic decrement of the incident earth wave is

$$\delta = \pi\frac{\kappa}{\omega}; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4.12)$$

hence

$$\left.\begin{aligned} (\beta_j)_{\max} &= 4\pi\frac{g_j}{\mu_j^3} \cdot \frac{\omega_j}{\omega} \cdot \frac{1}{\delta} \\ \frac{\Delta\omega}{\omega_j} &= \frac{2\sqrt{3}}{\pi}\delta = 1.102\delta \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (4.13)$$

The lower of these two expressions shows that if the decrement i[s] small, there will be not much overlapping of the resonance curves belonging to the proper frequencies $\omega_1, \omega_2, \ldots$ A given earth wave will have no appreciable effect unless it be near to one of the proper frequencies. There-fore it may be assumed that in the upper expression the value of ω_j/ω is approximately 1, so that

$$(\beta_j)_{\max} \sim 4\pi \frac{g_j}{\mu_j^3} \cdot \frac{1}{\delta}. \quad \ldots \ldots \quad (4.15)$$

For large values of j, say for $j = 4, 5, \ldots$, there is the asymptotic law

$$\mu_j = (2j-1)\frac{\pi}{2}, \quad j = 4, 5, \ldots \quad \ldots \ldots \quad (4.16)$$

From the definition (equation 3.5) it follows that, for these values of j, $g_j \rightarrow 1$; hence

$$\frac{4\pi g_j}{\mu_j^3} = \frac{32}{(2j-1)^3 \pi^2}; \quad j = 4, 5, \ldots \quad \ldots \quad (4.17)$$

For small values of j, Rayleigh's values of μ_1, μ_2, μ_3 have to be used. Table I contains the result of the calculation of the numerical factor i[n] equation (4.15).

TABLE I.

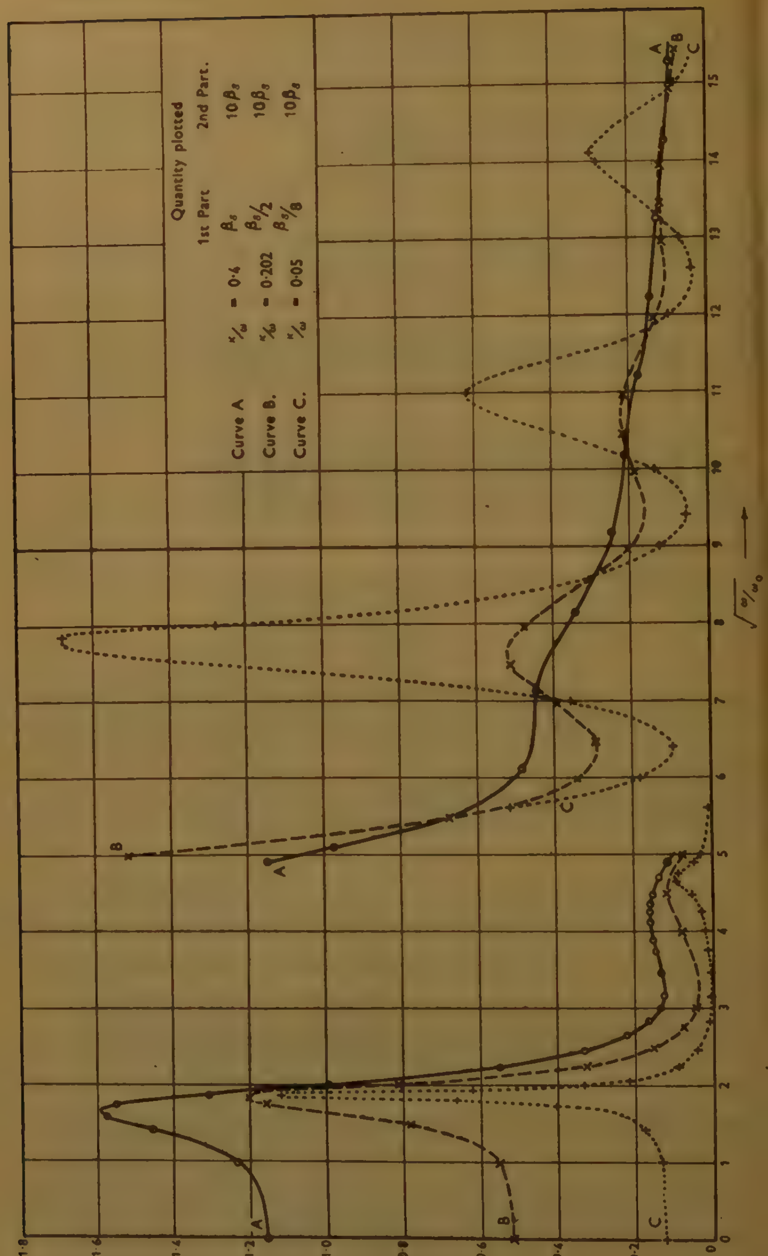
j	μ_j	g_j	$\frac{4\pi g_j}{\mu_j^3}$
1	1·875104	0·7338299	1·398715
2	4·694098	1·0184592	0·123736
3	7·854757	0·9992249	0·025910
4	10·995541	1·0000334	0·009453
5	14·137168	0·9999984	0·004448
6	17·278759	1·0000014	0·002436

Formula (4.17) and Table I show the rapid decrease of the resonanc[e] maxima with the number of the overtone. For $j = 4$ the height of th[e] maximum is already less than $0{\cdot}01/\delta$ of that of the fundamental vibratio[n,] that is, less than 2 per cent. for $\delta = 0{\cdot}5$, and less than 5 per cent. f[or] $\delta = 0{\cdot}2$. As the relative width is given by $1{\cdot}1\delta$, these resonance curv[es] overlap very little, and the sum β_f of their contributions to β is furth[er] weakened by interference, since the phases ϵ_j (equation 3.19) are changi[ng] from one to the other.

For small values of t the synchronous part β_s has to be added to β[...] It is clear that this cannot change the order of magnitude of the resonanc[e,] for the synchronous vibration is alone present in the initial stage of th[e] motion and excites the free vibrations gradually. Mathematically y_s [...] expanded in terms of y_j. In order to illustrate this, the maximum amplitu[de]

TABLE II.

$f=\kappa/\omega=0{\cdot}202$.			$f=\kappa/\omega=0{\cdot}4$.			$f=\kappa/\omega=0{\cdot}05$.					
ω/ω_0.	$\sqrt{\omega/\omega_0}$.	β_s.	ω/ω_0.	$\sqrt{\omega/\omega_0}$.	β_s.	ω/ω_0.	$\sqrt{\omega/\omega_0}$.	β_s.	ω/ω_0.	$\sqrt{\omega/\omega_0}$.	β_s.
0·0000	0·0000	1·0408	0·0	0·0000	1·1600	0·00	0·0000	1·0025	24·984	4·9984	0·24080
0·9900	0·99499	1·1166	1·0	1·0000	1·2325	1·00	1·0000	1·0810	31·340	5·5982	0·051952
2·2275	1·4925	1·5687	2·0	1·4142	1·4578	2·00	1·4142	1·4271	35·978	5·9981	0·018086
3·0319	1·7412	2·3140	2·5	1·5811	1·5785	3·00	1·7320	3·2587	40·934	6·3980	0·0096203
3·3883	1·8407	2·4081	3·0	1·7320	1·5520	3·25	1·8028	5·3317	48·969	6·9978	0·035862
3·9600	1·9900	1·6254	3·5	1·8708	1·3099	3·50	1·8708	8·9724	61·427	7·8375	0·16783
5·0119	2·2387	0·65558	4·0	2·0000	0·99466	3·75	1·9365	4·9827	63·960	7·9975	0·12740
6·1875	2·4875	0·30467	5·0	2·2361	0·55198	4·00	2·0000	2·7024	80·949	8·9972	0·012398
7·4869	2·7362	0·15069	6·0	2·4495	0·33312	4·25	2·0616	1·7530	88·305	9·3971	0·0052640
8·9100	2·9850	0·081200	7·0	2·6458	0·22160	5·00	2·2361	0·74981	99·938	9·9969	0·013717
15·840	3·9800	0·15076	8·0	2·8284	0·16386	6·00	2·4495	0·34938	120·92	10·997	0·061721
20·048	4·4774	0·22332	9·0	3·0000	0·13652	8·00	2·8284	0·093620	143·91	11·996	0·0095694
24·750	4·9749	0·15136	10·0	3·1623	0·12725	10·00	3·1623	0·052851	158·66	12·596	0·0038688
29·948	5·4724	0·067628	12·0	3·4641	0·13131	12·00	3·4641	0·061698	168·89	12·996	0·0065642
35·640	5·9699	0·034442	14·0	3·7417	0·14481	14·00	3·7417	0·10468	195·88	13·996	0·028147
41·818	6·4674	0·029594	15·0	3·8730	0·15130	16·00	4·0000	0·15324	199·25	14·116	0·029606
48·510	6·9649	0·039402	17·0	4·1231	0·15970	18·00	4·2426	0·22959	224·86	14·995	0·0079008
55·688	7·4624	0·051157	18·0	4·2426	0·15950	20·00	4·4721	0·40764	255·84	15·995	0·0037678
63·360	7·9599	0·047556	19·0	4·3589	0·15802	21·50	4·6368	0·73673			
80·190	8·9549	0·020507	20·0	4·4721	0·15283	22·00	4·6904	0·79410			
99·000	9·9499	0·018485	22·0	4·6904	0·13615	22·50	4·7434	0·70920			
109·15	10·447	0·021351	24·0	4·8990	0·11446	24·00	4·8990	0·35103			
119·79	10·945	0·021278	25·939	5·093	0·097292						
142·56	11·940	0·013259	37·344	6·111	0·048106						
167·31	12·935	0·011080	50·837	7·130	0·044367						
180·43	13·432	0·011760	66·390	8·148	0·034127						
194·04	13·930	0·011823	84·034	9·167	0·024290						
222·75	14·925	0·0090208	103·75	10·186	0·021020						
237·85	15·422	0·0078998	125·53	11·204	0·017443						
			149·38	12·222	0·014190						
			175·32	13·241	0·012325						
			203·35	14·260	0·010650						
			233·42	15·278	0·0091848						
			265·59	16·297	0·0072867						



Quantity plotted
1st Part 2nd Part
Curve A κ/ω = 0·4 β_s 10β_s
Curve B. κ/ω = 0·202 β_s/2 10β_s
Curve C. κ/ω = 0·05 β_s/8 10β_s
A
B
C
√(ω/ω₀)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
0 0·2 0·4 0·6 0·8 1·0 1·2 1·4 1·6 1·8

Fig. 1.

of β_s, given by the coefficient of $\sin(\omega t + \epsilon)$ in equation (4.3), has been calculated,

$$\beta_s = \frac{2\sqrt{1+\frac{\kappa^2}{\omega^2}}}{\omega/\omega_0}\sqrt{a^2+b^2}, \quad . \quad . \quad . \quad . \quad . \quad (4.18)$$

as a function of ω for some values of κ (Table II). The results are contained in *Fig. 1*, which shows that $\beta_s(\omega)$ looks like a superposition of the single resonance curves; the maxima at ω_1, ω_2, . . . decrease rapidly in height.

An increase of the sum of all vibrations by the total amount of $\beta_s(\omega)$ in the moment of its maximum amplitude will hardly ever happen, since the phases of all terms are different. Thus it would seem that for the neighbourhood of a resonance point the simple addition of $\beta_s(\omega)$, as given by the curve in *Fig. 1*, to the corresponding value of $\beta_f(\omega)$ given by Table II would represent a reasonable upper limit to the maximum resonance factor β. Further, for points in the region between two resonance maxima, produced by two of the free vibrations, an estimate of β may be made by adding the contributions of the two free vibrations at the point in question to $\beta_s(\omega)$. It should also be remembered that in the model, internal damping has been neglected. In actual fact a cantilever will always be damped by internal friction; this will affect the higher harmonics more than the fundamental and will increase with the order j. The part played by the higher harmonics will therefore be still smaller than that estimated.

The paper is accompanied by one sheet of drawings, from which the Figure in the text has been prepared.

Paper No. 5300.

"Soil Mechanics: The Factor of Safety of Clay Banks."[1]

(Ordered by the Council to be published with written discussion.)

By Ernest Cecil Smith, Ph.D., M.Sc. (Eng.), M. Inst. C.E.

The object of this Paper is to present an extension of the ϕ-circle method of investigating the stability of a clay bank of any shape to enable it to be used for finding the factor of safety of the bank.

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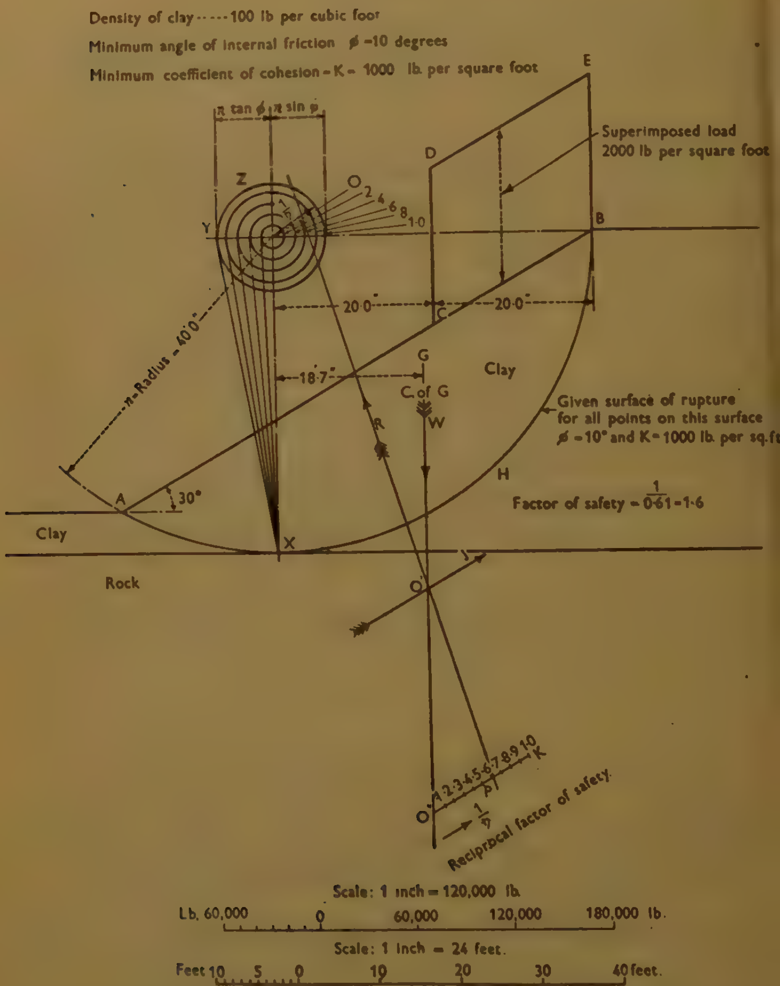
[1] Correspondence on this Paper can be accepted until the 15th August, 1942, and will be published in the Institution Journal for October 1942. Contributions should be limited to 300 words.—Sec. Inst. C.E.

Fig. 1 illustrates a clay bank, which may be of any shape and loaded with any number of superimposed loads. The surface of rupture is assumed to be the circular arc AXB. If the surface of rupture is not known, th

Fig. 1.



Construction for Finding the Factor of Safety η of a Clay Surface.

construction which follows would have to be repeated for a few trial surfac of rupture until the surface of rupture which gives the lowest value for t factor of safety is found.

Let ϕ denote the angle of internal friction of the clay, and K its coefficient of cohesion; then the resistance of the clay to shear can be expressed as $K + N \tan \phi$, where N denotes the normal pressure on the clay. If the bank has a factor of safety of η the shear stress in the clay would be $\dfrac{K + N \tan \phi}{\eta}$.

Let the length of the surface of rupture be denoted by S, and the length of the chord which joins the extremities of the surface of rupture by C. As in the ordinary construction for the ϕ-circle method, draw O′J parallel to the chord joining the extremities of the surface of rupture, and at a distance OO′ from O equal to $r \times \dfrac{S}{C}$, where r denotes the radius of the surface of rupture, and O the centre of the circular arc AXB. Through the centre of gravity of the total load W, produced by the mass of earth above the surface of rupture and the superimposed load, draw the vertical GO′O″ to cut O′J at the point O′, then mark off the distance O′O″ to represent the load W to a convenient scale. From O″ draw O″K parallel to O′J, mark off the distance O″K $= K \times C$, and divide O″K into ten equal parts. Then with centre O and radius OZ $= r \sin \phi$, draw the friction circle, and concentric with it draw nine further circles with radii equal to $r \sin \left(\tan^{-1} \dfrac{\tan \phi}{10}\right)$; $r \sin \left(\tan^{-1} \dfrac{\tan \phi}{9}\right)$; $r \sin \left(\tan^{-1} \dfrac{\tan \phi}{8}\right)$; etc. Starting from the smallest circle, let the circles be marked 0·1, 0·2, 0·3 . . . etc.; then these values will represent reciprocals of the factors of safety; that is, the friction circles will correspond to factors of safety of 10, 9, 8 . . . etc. These circles can most readily be drawn by the following construction: from the point O draw the vertical line OX to cut the surface of rupture at X, and draw XY to make an angle ϕ with OX. Then divide YO into ten equal parts, join the points so obtained to X, and with centre O draw a series of concentric circles to touch these lines. In *Fig. 1* YO has been divided into five parts instead of ten, to enable the construction to be more readily followed.

The factor of safety of the slope is then found by passing a straight-edge through the point O′ and rotating it until the number on the friction circle agrees with the number on the scale O″K. This number is the reciprocal of the factor of safety, so that its reciprocal gives the required factor of safety.

Fig. 1 indicates the solution for a clay bank with a given surface of rupture. To simplify the work, the density of the clay has been taken as 100 lb. per cubic foot, and the clay at the surface of rupture is assumed to have an angle of internal friction of 10 degrees, and a coefficient of cohesion of 1,000 lb. per square foot.

By applying the construction given above, it will be seen that $\dfrac{1}{\eta} = 0{\cdot}61$,

so that the factor of safety of the bank would be $\frac{1}{0{\cdot}61} = 1{\cdot}6$. The metho now in use for estimating the factor of safety consists in drawing a lin through O′ to touch the friction circle ($\phi = 10$ degrees) and to cut the li O″K at P, and regarding the factor of safety as $\frac{O''K}{OP}$. In the examp given above this would give approximately 2, instead of 1·6, for the valu of the factor of safety.

The Paper is accompanied by one sheet of drawings, from which *Fig.* has been prepared.

Paper No. 5302.

"Effect of Rate of Loading on the Mechanical Properties of some Materials."

By Rhydwyn Harding Evans, M.Sc., Ph.D., Assoc. M. Inst. C.E.

(*Ordered by the Council to be published with written discussion.*†)

Introduction.

A knowledge of the mechanical properties of materials when subject to high rates of loading is of considerable importance in several branch of engineering. Many investigators[1] have examined the properties metals at either comparatively low testing-speeds or very high speeds, t former in screw-powered testing-machines and the latter in impact testin machines. No tests seem to have been made on metals over a continuo range of loading speeds, whilst in the case of crushing tests on concre cubes the only tests known to the Author have been made by D. Abrams[2], and by P. G. Jones and F. E. Richart[3], in which the short

† Correspondence on this Paper can be accepted until the 15th August 1942, a will be published in the Institution Journal for October 1942. Contributions sho be limited to 300 words—Sec. Inst. C.E.

[1] H. Quinney, *The Engineer*, vol. 157, p. 332, 1934 ; vol. 161, p. 669, 1936 ; D. Ginns, Journal Inst. of Metals, vol. 61, p. 61, 1937 ; H. C. Mann, Proc. Amer. S Test Mat., vol. 36, part II, p. 85, 1936.

[2] D. A. Abrams, Proc. Amer. Soc. Test Mat., vol. 17, part II, p. 364, 1917.

[3] P. G. Jones and F. E. Richart, Proc. Amer. Soc. Test Mat., vol. 36, part II, p. 3 1936.

time of loading was only 1 second. The rate of loading in compressive and tensile tests on concrete is specified both in British Standard Specification No. 12 (1940) for Ordinary Portland and Rapid Hardening Portland Cements, and in the "Handbook on the Code of Practice for Reinforced Concrete." In the former the specified rate of loading is 5,000 lb. per square inch per minute for the cube crushing tests, and 100 lb. per square inch of section per 12 seconds for the briquette tests, whilst in the latter the specified rate is 2,000 lb. per square inch per minute for the crushing tests. The Author's investigation was undertaken to study the effect of the rate of loading upon (*a*) the crushing strength of rich and lean mixes of concrete, and (*b*) the yield-point, ultimate or tensile strength, percentage elongation, and reduction of area of mild steel, duralumin, and brass (Muntz metal), and the tensile strength of cast iron.

Experimental Apparatus and Procedure.

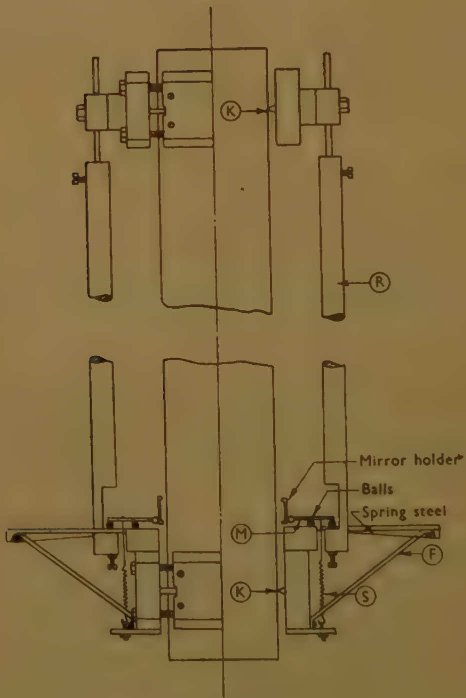
The testing-machine, which has already been briefly described by the Author[1], consists essentially of a hydraulic ram, 16 inches in diameter, operated by compressed air and capable of applying any load up to 15 tons. The cylinder is mounted on four tension-rods, each $2\frac{1}{4}$ inches in diameter and of sufficient length to give a clear space of 6 feet between the ram and the machine base. The cylinder is connected to the compressed-air tank by a vertical bend, about 6 feet long, fitted with two quick-acting valves and one release cock, one quick-acting valve being attached as close as possible to the cylinder top and the other to the top of the compressed-air tank. The cylinder clearance volume is filled with oil until its level is slightly above the quick-acting valve attached to the cylinder, the correct level of the oil being maintained by an oil-reservoir connected to the cylinder-top. A valve isolates this oil-reservoir before any air-pressure is applied to the machine. Variation of the rate of loading is obtained by opening the valves at different speeds, the valve on top of the machine being used for the high speeds and the valve on top of the air-tank for the low speeds. The compressed air forces the ram downwards on to the test-specimen and, after the latter has fractured, the ram continues its downward motion until it is brought to rest by stops consisting of lead blocks resting on channels attached to the four tension-rods.

The load on the test-specimen is observed by recording the compressive strain in a square mild-steel load-column to which is attached a specially-designed extensometer. Details of the extensometer are shown in *Fig. 1*, use being made of the optical lever principle to magnify the strain of the load-column. Two collars, with knife-edges K, are fixed 20 inches apart on the column. A rigid frame F is attached to the lower collar to allow the rods R to move in a vertical direction by means of spring steel strips.

[1] R. H. Evans, Proc. Leeds Phil. Soc., vol. 3, part XI, p. 584, 1940.

The mirror-plate M carries three balls, each $\frac{1}{16}$-inch diameter, two of which rest on the lower collar and the third rests on a set-screw in the end of rod R. The mirror is maintained in position by means of springs S which hold the mirror plates M down firmly on the three balls. The same arrangement is used at each side of the load-column. The strain in the load-column is thus transmitted to the rods R and these in turn cause the mirrors to rotate in opposite directions so that any error due to the tilting

Fig. 1.



DETAILS OF EXTENSOMETER.

of the load-column is eliminated. The magnification is also doubled, its magnitude being $\frac{4L + 2l}{d}$, where L denotes the distance from the film drum to the appropriate mirror, l the distance between the two mirrors and d the distance between the centre-lines of the balls. A spot-light is reflected from the mirrors on to a film fixed to a drum rotating about a vertical axis, any rotation of the mirrors causing the spot to move vertically over the film.

The calibration of the extensometer under slow loading was carried out with a lever testing-machine. The behaviour of the extensometer under

rapid loads was first examined by placing two identical extensometers on two steel columns in series in the compressed-air machine. Film records were taken of the strains in each column during rapid loading and, on examination, it was found necessary to make the extensometer parts very rigid and to increase the pressure on the mirror plates M by very strong springs S. Since carrying out experiments on the instantaneous strains in building materials[1], in which the minimum loading-time was about $\frac{1}{140}$ second, it has been found that the speed of the machine could be increased considerably by using oil of much lower viscosity. This necessitated checking the accuracy of the machine at much higher loading-speeds than had hitherto been used. For this purpose an optical indicator, which is normally used to record the cylinder-pressure in high-speed steam-engines, was fixed to the machine cylinder. The optical indicator was first calibrated slowly against the extensometer on the load-column in the compressed-air machine, a steel block taking the place of a concrete cube. Afterwards film records were taken off the extensometer and optical indicator during the crushing of concrete cubes, the reflecting mirror of the optical indicator being displaced horizontally by the opening of the quick-acting valve in order to obtain simultaneous horizontal and vertical displacements. The agreement between the indicator and the extensometer was found to be very satisfactory up to loading-speeds of $\frac{1}{300}$ second. At higher loading-speeds the optical indicator gave too high a reading, denoting overshooting of the mirrors. This was later confirmed by taking film records with the concrete cube replaced by a steel block so that the maximum air-pressure could be applied to give a load of 15 tons. The extensometer began to overshoot when tested with the steel block at loading speeds of about $\frac{1}{500}$ second. In the cube crushing tests, however, the maximum load required to crush the cubes was about 9 tons, which meant that the angle of rotation of the mirrors was reduced correspondingly. Therefore, it is reasonable to assume that the crushing tests are reliable for greater loading speeds than $\frac{1}{500}$ second.

The cubes were made in batches of eighteen; aluminous cement was used throughout, and six cubes from each batch were crushed in a lever testing-machine to determine the average crushing strength of each batch. All cubes of the same mix could be then corrected to some standard strength, this procedure being necessary to allow for any slight differences in the crushing strength of each batch of cubes. The slow crushing tests on cubes were carried out in a lever testing-machine with the load increased in small increments at intervals depending upon the time to be taken in crushing the specimen.

In the metal tests two U-frames were necessary to adapt the machine for tensile tests. One U-frame was fixed to the ram, and the other to the load column in the inverted position with its cross-piece above and approxi-

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[1] R. H. Evans, Proc. Leeds Phil. Soc., vol. 3, part XI, p. 584, 1940.

mately perpendicular to the cross-piece of the frame fixed to the ra[m]. The tension specimens were held in the cross-pieces by means of screwe[d] split-grips with spherical seatings. Any downward motion of the ra[m]

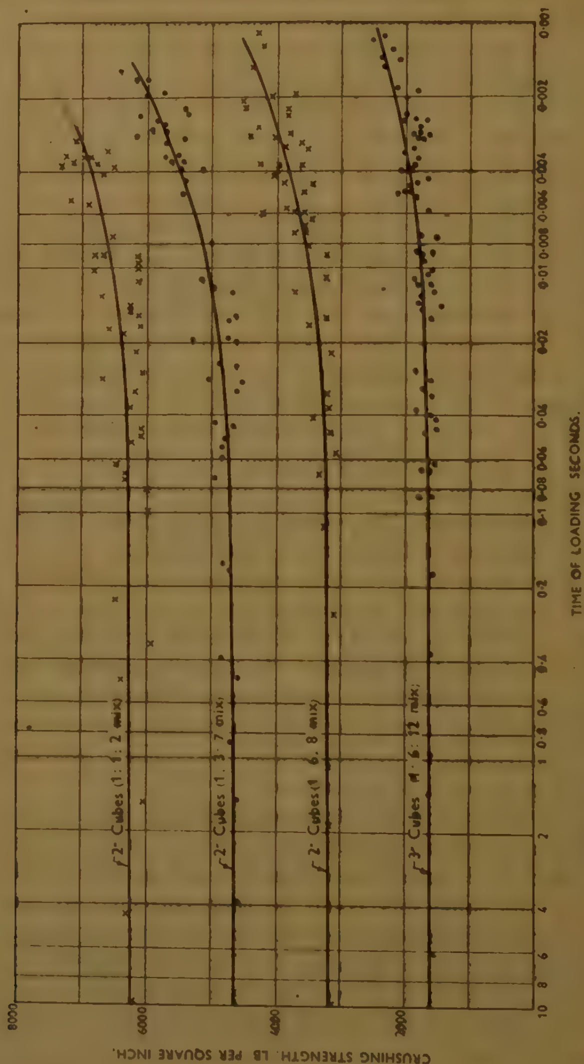


Fig. 2.

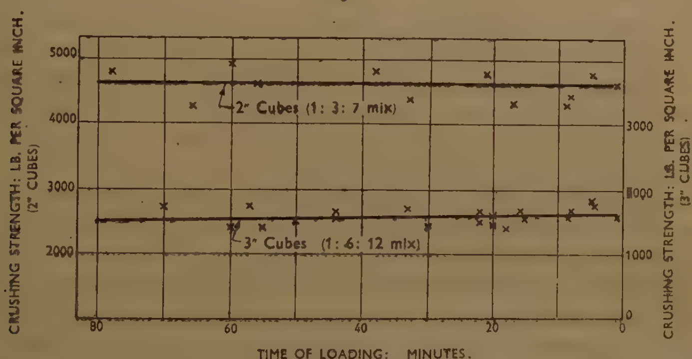
EFFECT OF RATE OF LOADING ON CRUSHING STRENGTH OF CONCRETE.

causes the two cross-pieces to move apart and to induce tension in the tes[t] specimens. The gauge-length in all the metal tests is $4\sqrt{\text{area}}$, or 3·5 diameters. After fracture the percentage elongation and reduction [of] area were measured.

Experimental Results and Discussion.

The results of the crushing tests on 2-inch and 3-inch concrete cubes are shown in *Figs. 2* and *3*, the time of loading in *Fig. 2* being plotted to a logarithmic scale. Some examples of the film records taken are shown in *Figs. 4*, the horizontal length of the record depending upon the speed of rotation of the drum. The curves in *Fig. 2* for various concrete mixes indicate no definite increase in the crushing strength for loading speeds as fast as $\frac{1}{20}$ second, whilst for faster speeds there is a marked increase. It also seems that the percentage increase in crushing strength with increase of loading speed is higher for the lean mixes than for the rich

Fig. 3.



Effect of Rate of Loading on Crushing Strength of Concrete.

mixes. Thus, at a loading speed of $\frac{1}{500}$ second, the percentage increase is 17, 28, 31, and 35 respectively, for concrete mixes of 1 : 3, 1 : 10, 1 : 14, and 1 : 18. An examination of *Fig. 3* for times of loading ranging up to 80 minutes shows little change in the crushing strength. This conclusion agrees with that of Richart and Brown[1], but not with those of Abrams [2] and Jones and Richart[3]. Abrams, using a lever testing-machine and 6-inch by 12-inch concrete cylinders, found that the crushing strength for a rate of strain of 0·15 inch per minute was from 14 to 20 per cent. greater than that for a rate of strain of 0·006 inch per minute. Jones and Richart, again using 6-inch by 12-inch cylinders with autographic records of the load and strain, found that the crushing strength increased by about 33 per cent. when the time of loading was reduced from 4 hours to 1 second. A check by the Author on the effect of the loading-speed upon the crushing strength of concrete was made by testing a series of

[1] F. E. Richart and R. L. Brown, Univ. of Illinois Bulletin No. 267, 1934.

[2] *Loc cit.*

[3] *Loc. cit.*

thirty 4-inch cubes, having a normal crushing load of 30 tons, in a 200-to hydraulic crushing-machine. The maximum loading-speed, which wa obtained by making the stroke of the Hele-Shaw pump a maximum, wa estimated to be $\frac{1}{2}$ second, and a graph of the results obtained showed like *Fig. 3*, no definite increase of the crushing strength.

It is obvious from the results in *Figs. 2* and *3* that the effect of the rat of loading upon the crushing strength depends very largely upon the typ of testing machine used, and that with hydraulic testing-machines th crushing strength is essentially constant at all loading-speeds up to $\frac{1}{2}$ second. It is doubtful whether any standard lever testing-machine coul have a maximum loading-speed of $\frac{1}{2}$ second and whether the weigh-bean could be accurately balanced, by moving the poise-weight, for loading speeds as rapid as 30 seconds. Rapid loading in lever testing-machines such as that employed by Abrams[1], introduces errors due to the inerti of the moving levers and to the difficulty of balancing the weigh-beam.

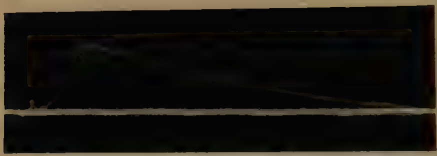
With regard to tensile tests on concrete, it is thought that concret in tension would behave much in the same way as cast iron in tension and as will be seen later, the tensile strength of cast iron is sensibly constan for all loading-speeds lower than $\frac{1}{20}$ second.

Examples of the film records taken during the metal tests are als shown in *Figs. 5* for mild steel and duralumin. A difficulty that wa experienced in testing the ductile materials was the excessive vibratio induced at the beginning of the film trace as the split-grips took up th strain. This was overcome by applying an initial load, equivalent to abou one-third the yield stress, before the specimen was tested to destruction The distance between the two horizontal lines in *Figs. 5* is therefore measure of the initial load applied, the upper line being produced after th application of the initial load, and the lower line after the specimen ha been fractured. In order to obtain the zero load-point of the film trac for calculating the loading-speed, the film trace was produced backward to cut the lower horizontal line; no serious error was involved in this as the rate of loading is fairly uniform up to the yield-point. Som vibration was sometimes also set up during the plastic yielding of th specimen, as illustrated in *Figs. 5* for mild steel, but by drawing a mea line through the wavy portions of the film trace the maximum load ca be determined satisfactorily. The testing-speeds of the ductile material are naturally much lower than those for concrete or cast iron, owing to th elongation involved. Also, as the time taken to fracture depends upon th gauge-length, the tensile strength, yield-point, percentage elongation, an reduction of area have been plotted in *Figs. 6* and *7* against the mean rat of strain, this being the percentage elongation divided by the time take to fracture.

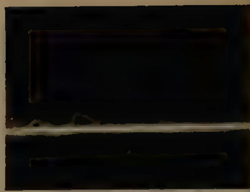
Referring to *Fig. 6*, it will be seen that ductile materials differ to som extent in the manner in which the yield-point and tensile strength var

[1] *Loc. cit.*

Figs. 4.

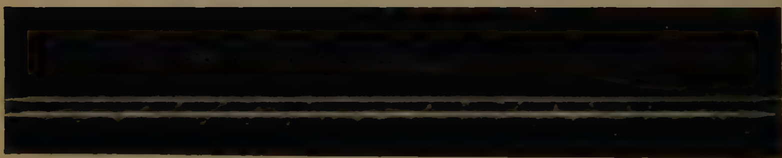


3-INCH CONCRETE CUBE. CRUSHING LOAD 9·75 TONS. TIME TO CRUSH 1/32 SECOND.

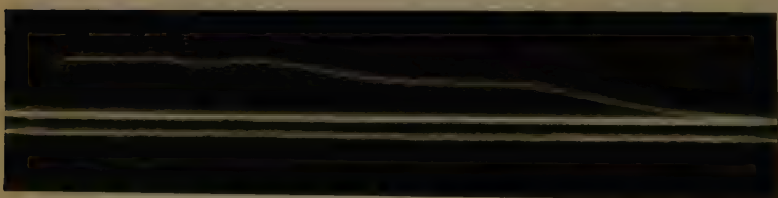


2-INCH CONCRETE CUBE. CRUSHING LOAD 9·4 TONS. TIME TO CRUSH 1/500 SECOND.

Figs. 5.



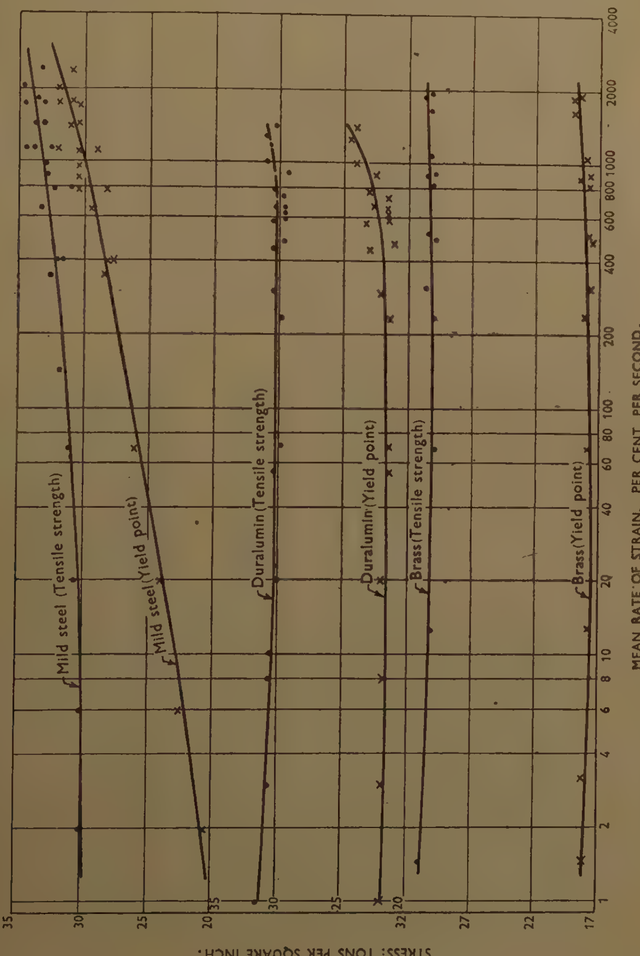
MILD STEEL: YIELD POINT 7·63 TONS. TIME TO YIELD 1/63 SECOND. MAX. LOAD 8·6 TONS. TIME TO FRACTURE 1/26 SECOND.



DURALUMIN: YIELD POINT 5·3 TONS. TIME TO YIELD 1/23 SECOND. MAX. LOAD 7·4 TONS. TIME TO FRACTURE 1/12 SECOND.

with the rate of strain. For mild steel there is a marked increase in the yield-point as the rate of strain increases, the yield-point being 50 per cent. higher when the rate of strain is 1,000 per cent. per second. The tensile strength of mild steel also increases with increase of rate of strain, but to a smaller degree than the yield-point, so that when the rate of strain is

Fig. 6.



EFFECT OF RATE OF STRAIN ON YIELD POINT AND TENSILE STRENGTH.

about 10,000 per cent. per second the yield-point becomes equal in magnitude to the tensile strength. Some interesting examples of the difference between the effects of slow and rapid straining rates occur in practice and can be explained by the fact that the yield-point of the material is raised during the rapid straining rate. Thus, in the case of bar or ingot breaking

machines there is less obvious deformation or permanent set and a more regular fracture in quick-acting machines operated by compressed air than in slow-acting machines operated off an eccentric or hydraulically. Again, in the case of a hole punctured slowly in a mild-steel plate and rapidly,

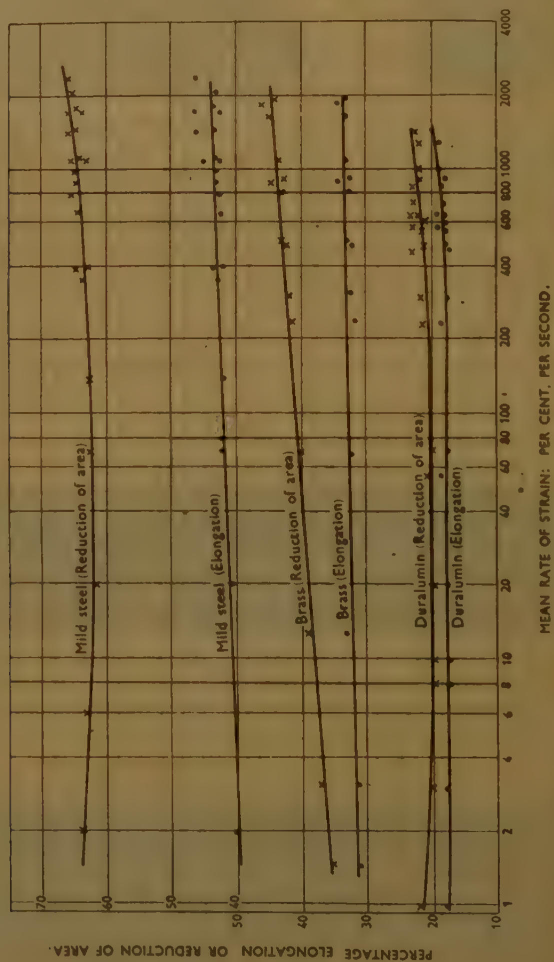


Fig. EFFECT OF RATE OF STRAIN ON ELONGATION AND REDUCTION OF AREA.

as by a bullet, the deformation around the hole is less obvious in the case of the bullet, and the Lüder's lines extend to a great distance from the centre of the hole.

The yield-point of duralumin increases very little until comparatively high rates of strain are reached, whilst that of brass (Muntz metal) shows no change. The tensile strength of both duralumin and brass is practically

independent of the rate of strain; all these results relating to mild steel, duralumin, and brass agree with those of Ginns[1], Jones and Moore[2], Fry[3], and Brown and Vincent[4]. The fact that the results in *Fig. 6* agree with those of other investigators is an indirect check on the reliability of the optical extensometer at high loading-speeds.

The tensile strength of cast iron at different loading-speeds is given in Table I, from which it will be observed that the tensile strength begins to increase appreciably when the time of loading is less than $\frac{1}{20}$ second.

TABLE I.

Time to fracture: seconds.	Tensile strenth: tons per sq. in.	Time to fracture: seconds.	Tensile strength: tons per sq. in.
10	11·97	0·0071	13·20
0·366	12·20	0·0070	14·04
0·0614	11·96	0·0052	14·20
0·031	12·20	0·0050	14·08
0·014	13·64	0·0045	15·06
0·0109	13·20	0·0036	15·08
0·0095	13·86	0·0035	14·48
0·008	13·60	0·0034	14·98

The effect of rate of strain upon the percentage elongation and reduction of area is illustrated in *Fig. 7* for mild steel, duralumin, and brass. It will be seen that mild steel and brass show a slight increase in both percentage elongation and reduction of area with increase of rate of strain, whilst duralumin is unaffected except at high rates of strain.

The only remaining point that requires some explanation is the difference between the effect of rapid straining upon the yield-point and tensile strength of mild steel and of duralumin and brass. One possible explanation is that plastic deformation can take place in two ways: (*a*) by gliding; (*b*) by twinning[5]. The deformation by gliding occurs on particular planes parallel to the glide planes, one part of the crystal slipping relatively to the other so that the planes on which slipping occurs are approximately equally spaced. The plastic deformation by twinning is always a form of homogeneous deformation, every lattice plane moving the same amount as every other relatively to its immediate neighbours. The relation between plastic deformation and structure is obscure, no connexion having yet been traced between them. Twinning may occur

[1] *Loc. cit.*

[2] P. G. Jones and H. F. Moore, Proc. Amer. Soc. Test Mat., vol. 40, p. 610, 1940.

[3] L. H. Fry, Proc. Amer. Soc. Test Mat., vol. 40, p. 625, 1940.

[4] A. F. C. Brown and N. D. G. Vincent, Proc. I. Mech. E., vol. 145, No. 3, p. 126, 1941.

[5] E. N. da C. Andrade, Journal Inst. C.E., vol. 16 (Session 1940–41), p. 287 (June 1941).

by simple rotation about a twin axis, or by gliding, the difference bein that all faces preserve their form in the former and generally change it i the latter. Twinning by gliding occurs in a number of substances, includin metal crystals. Another important difference between the plastic deforma tion produced by gliding and twinning is that it takes time to appear i the former, whilst it can appear in a very brief interval of time in th latter. An increase of the rate of straining will therefore increase th yield-point of metals deformed plastically by gliding, such as mild steel but will have little effect upon those deformed by twinning.

The Paper is accompanied by five sheets of diagrams and one shee of photographs, from which the half-tone plate and the Figures in th text have been prepared.

Paper No. 5305.

"An Investigation of the Bearing Capacity of a Soft Clay Soil." †

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(Ordered by the Council to be published with written discussion.) [1]

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INTRODUCTION.

DURING the construction of the roof of a single-storey building the most heavily loaded footing settled quite rapidly by nearly 1 foot, and caused considerable structural damage. Such a settlement indicates a failure in shear of the underlying soil which, in this case, was a soft plastic clay: or, expressed more simply, the ultimate bearing capacity of the clay had been exceeded.

There are several methods of calculating the ultimate bearing capacity of clay soils, and by the application of a suitable factor of safety, they enable the permissible loading to be determined[2]. They are also of comparatively simple application to foundation problems, since they depend principally upon a knowledge of the shear strength of the clay; and this

[1] Correspondence on this Paper can be accepted until the 15th August 1942, and will be published in the Institution Journal for October 1942. Contributions should be limited to 300 words.—SEC. INST. C.E.

[2] This applies to those foundation problems where it is necessary to guard against only the excessive settlements which occur when the loading approaches the ultimate bearing capacity. Where comparatively small differential settlements are of importance it is necessary to carry out a settlement analysis. This question has been discussed by Professor K. Terzaghi, M. Inst. C.E., "The Actual Factor of Safety in Foundations." *Struct. Eng.*, vol. 13, No. 3, p. 126 (March 1935).

can be easily measured by testing undisturbed samples obtained in the usual manner [1, 2]. But the methods do not all lead to identical results, whilst there is, unfortunately, very little published information concerning their reliability in practice. Consequently, when the Building Research Station was requested to report on the above-mentioned failure, and to advise on the remedial measures, the opportunity was taken of checking the ultimate bearing capacity of the clay, as calculated by the various theoretical methods, against the actual ultimate bearing capacity as shown by the load acting on the footing at the time of failure.

The investigation falls, therefore, under four main headings :—

(1) Determination of the actual ultimate bearing capacity.
(2) Measurement of the shear strength of the clay.
(3) Calculation of the ultimate bearing capacity from the shear strength, using the various theoretical methods available.
(4) Comparison of the calculated with the actual ultimate bearing capacity, and in this way to study the reliability of the methods in relation to the full-scale failure.

For convenience, the " ultimate bearing capacity " will be referred to as simply the " bearing capacity " throughout the remainder of this Paper.

The Actual Bearing Capacity.

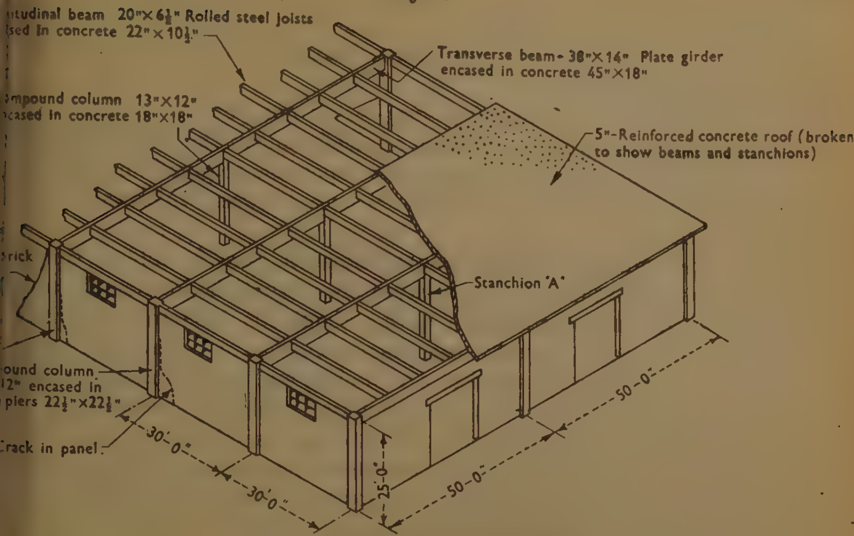
Description of the failure.—The building was a single-storey steel frame structure with brick panel walls. An isometric sketch is given in *Fig.* 1 and a foundation plan in *Fig. 2*, from which it can be seen that the building was divided lengthwise into six bays each 30 feet long. The footings of the central line of stanchions were of mass concrete 8 feet by 9 feet in plan and they were founded, in September 1939, at a depth of 5½ feet on what appeared to be a moderately good clay. By the end of January 1940 the frame and walls had been completed and the concrete roof was then cast over the first bay, starting from the east end. This took about two weeks. After an interval of one week the second bay was cast, and again the operation lasted about two weeks.

After casting the first bay no settlement of any of the stanchions had been observed, but a day or two after finishing the second bay it was found that Stanchion " A " had settled by about 3 inches. This was the most heavily loaded stanchion since it was carrying its full roof load. A few days later, nearly one week after casting the roof, a set of levels was taken

[1] M. J. Hvorslev, " The Present Status of the Art of Obtaining Undisturbed Samples of Soil." Committee on Sampling and Testing. Soil Mechanics and Foundations Division, Am. Soc. C.E. Cambridge, Mass. March 1940.

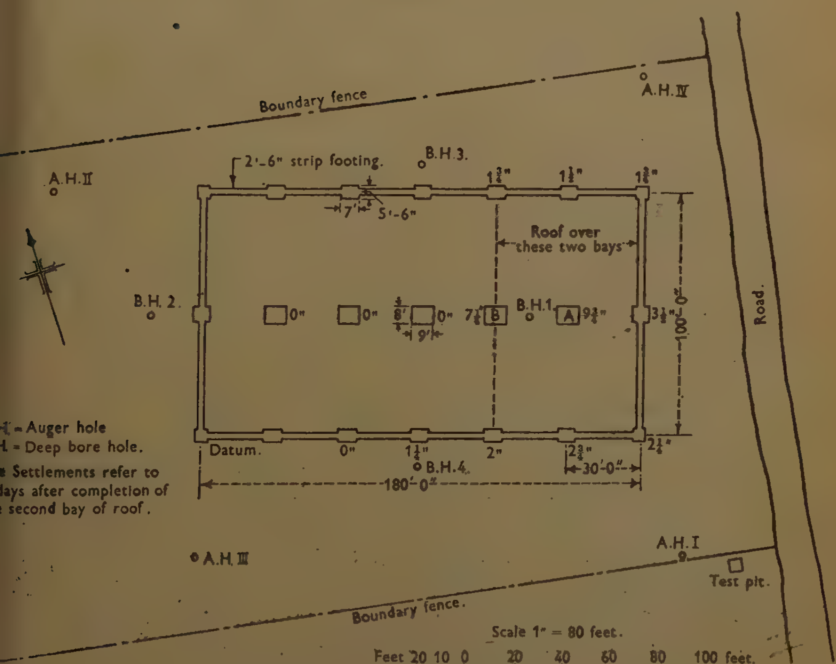
[2] L. F. Cooling, " Soil Mechanics and Site Exploration." Journal Inst. C.E. vol. 18 (1941–42), p. 37 (March 1942).

Fig. 1.



ISOMETRIC SKETCH OF BUILDING.

Fig. 2.



SITE AND FOUNDATION PLAN.

from the corner footing marked " datum " in *Fig. 2*, and stanchion A had then settled about 10 inches. Settlements at other points are given in *Fig. 2*. By this time the panel walls were severely cracked and the steelwork was distorted.

Structural load at the time of failure.—It is not possible to determine with a high degree of accuracy the load on the footing at the time of failure; but on the basis of certain assumptions it is possible to give limits, with range sufficiently small for the present purpose, between which the actual value must lie.

If it is assumed that the frame connexions were flexible, a simple estimate from the weight of the structure, shows that the load on the clay beneath the footing of stanchion A was about 105 tons when the two bays had been cast. Actually the connexions had a certain degree of rigidity, since they were formed of a web cleat and flange bracket, and a rough calculation indicates that the load was probably about 110 tons provided there was no settlement of the stanchion relative to the walls. But there must, in fact, have been some settlement before the clay failed completely and a part of the stanchion load would be transferred to the walls. The value of 105 tons seems therefore to be a reasonable estimate for the load when two bays had been cast.

This is not necessarily the load at the time of failure, for it will be noticed that the adjacent stanchion B also suffered excessive settlement although loaded with only one bay. Probably it was dragged down to some extent by stanchion A; but it is not certain that this is a sufficient explanation, and it may well be that the bearing capacity of the clay beneath stanchion A was reached at some period during the casting of the second bay, before the load had reached the value of 105 tons. This value must therefore be regarded as an upper limit of the load at the time of failure.

An absolute lower limit can readily be found, since the weight of the first bay was acting on stanchion A for one week without any sign of settlement, and no such signs were reported until two weeks later when an extra 20 tons of roof load had been added. The load at the time of failure therefore cannot possibly be less than 85 tons. It would seem that the actual load is nearer the upper limit of 105 tons than the lower limit and therefore that no great error would be involved in taking it to be of the order of 100 tons.

The net bearing capacity.—The area of the footing was 72 square feet and the load of 100 tons corresponds to a pressure of 3,100 lb. per square foot. This is the gross pressure acting on the clay at foundation-level. The original pressure at this depth of 5½ feet in clay weighing about 110 lb. per square foot was 600 lb. per square foot; and the net increase of pressure acting on the clay was therefore 2,500 lb. per square foot. It is this value which is taken as the " actual bearing capacity " rather than 3,100 lb. per square foot, since the shear stresses set up in the clay by the

footing are proportional to the net increase and not to the gross pressure. This accords with the usual practice of quoting permissible loading. For example, in the general building clauses of the "Code of Practice for the use of Reinforced Concrete" [1] it is stated that the permissible load on any soil "may be exceeded by an amount equal to the weight of the material in which a foundation is bedded and which is displaced by the foundation itself."

SITE AND SOIL CONDITIONS.

Geology.—The building was situated in Scotland. Four borings were sunk soon after the failure to determine the soil profile and, as will be seen in *Figs. 3* (*a*), they showed that the footings were founded only 1 foot above a bed of soft blue clay. This bed was about 13 feet thick and merged into an overlying layer of firmer brown clay which was probably an oxidation product of the blue clay.

The clays were laid down in an estuary during the period of the 25-foot Raised Beach of Scotland and Northern Ireland, when the sea extended for a considerable distance up the valley [2]. Subsequent uplift of the land, which was probably completed in Neolithic times [3], brought the clays approximately to their present elevation and little change has occurred since.

Soil properties.—Small undisturbed samples of the clays were taken at various depths down to about 10 feet in each of the four auger-holes marked in *Fig. 2.* The samples were $1\frac{1}{2}$ inch in diameter and $3\frac{1}{2}$ inches long, and immediately after sampling they were tested in a portable compression apparatus. A hand auger was used for making the holes; the sampling and testing techniques followed the procedure described in two recent Papers [4, 5]. In this manner the compression strength of the clay was measured but, since the shear strength of clays is equal to half their compression strength [6], the shear strength was also known. This is, in fact, a simple way of determining the shear strength in the field, and the work was carried out by the Author and one assistant in four days.

In addition, a test-pit was sunk to a depth of 8 feet and five samples were taken at regular intervals as the examination proceeded. The standard $4\frac{1}{4}$-inch diameter sampling-tube [7] was used and samples 14 inches

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[1] Reinforced Concrete Structures Committee. H.M.S.O. 1933.

[2] C. H. Dinham, "The Geology of the Stirling District." Proc. Geol. Assoc., vol. 38, Part 4, p. 470. 1927.

[3] W. B. Wright, "The Quarternary Ice Age", p. 386. Macmillan, 1937.

[4] L. F. Cooling, *loc. cit.*

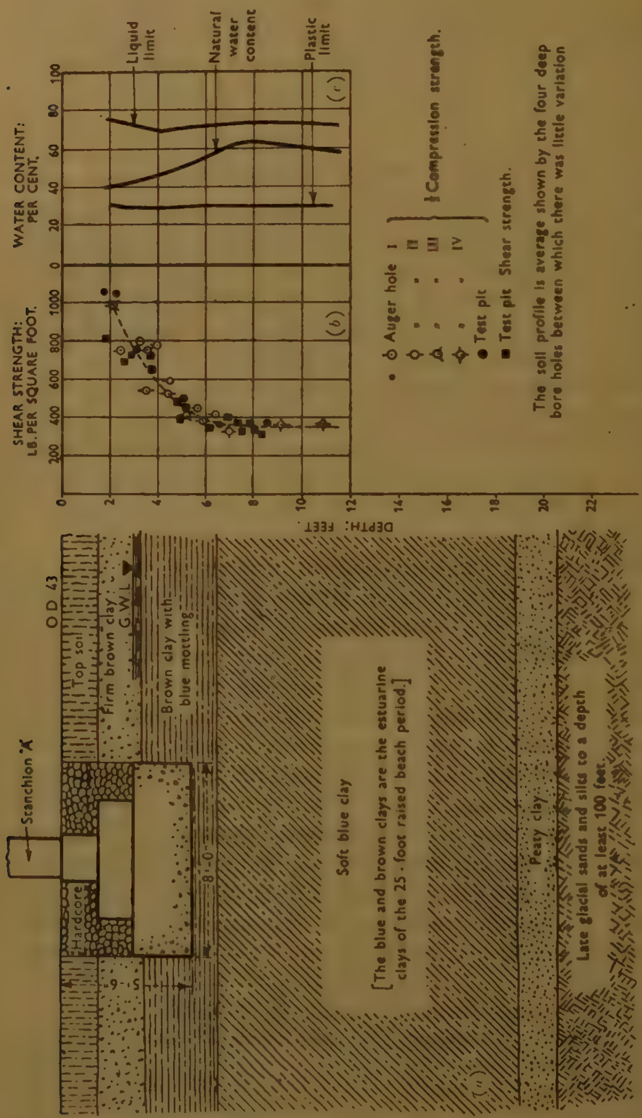
[5] L. F. Cooling and H. Q. Golder, "A Portable Apparatus for Compression Tests on Clay Soils." *Engineering*, vol. 149, p. 57 (19 January, 1940).

[6] See Appendix II.

[7] L. F. Cooling, *loc. cit.*

long were obtained by driving the tube into the bottom of the excavation as then exposed, and digging away the surrounding clay until the tube could

Fig. 3.



(*a*) Soil Profile. (*b*) Variation of Strength with Depth. (*c*) Water Content and Atterberg Limits.

be lifted out. The samples were transported to the laboratory, where a series of shear and compression tests were carried out. The main purpos

of these tests was to confirm the results of the auger-hole samples; and, as will be seen in *Figs. 3* (*b*) and in Appendix II, the agreement was satisfactory.

From *Figs. 3* (*b*) it will be seen that there was a very marked decrease in strength with increase in depth. The top soil contained many shrinkage cracks, which made its strength as a whole quite negligible, but immediately below the top soil the clay had a shear strength of 1,000 lb. per square foot. At 6 feet, however, the strength had fallen to 350 lb. per square foot and there was no definite evidence of an increase with greater depth.

The natural water-content and the Atterberg limits [1] of all the samples were determined; the results are summarized in *Figs. 3* (*c*). There was no essential change in soil type in the top 10 feet, since the liquid limit did not vary greatly from a value of about 70. But there was an increase in water-content from 40, near the surface, to 65 at a depth of 7 feet and the increase in strength as the surface is approached must therefore be due almost entirely to a drying out of the clay.

The soil conditions indicate that there was probably a seasonal fluctuation in ground-water-level between 3 feet and 6 feet approximately. If that were the case there would be a small seasonal change in strength of the clay between these depths; and it may be for this reason that the clay at foundation-level appeared moderately good when the footings were laid in September—a time when the ground-water is likely to be at its lowest level. A seasonal fluctuation in strength would not, however, affect the bearing capacity of the clay to any important extent, since the greater part of the clay resisting the footing load is below the zone which is subject to the fluctuations.

Calculation of Bearing Capacity.

General.—For clay soils the calculation of bearing capacity is based upon the assumption that the strength of the clay under a footing remains constant during the period of construction of a building, and equal to the strength of the clay in its natural state. The validity of this assumption depends upon two facts derived from the fundamental principles of soil mechanics established by Professor Terzaghi. Firstly, that a clay can increase in strength only if it is allowed to consolidate [2]; secondly, that the rate of consolidation is so slow that the amount of consolidation which takes place during the few months of construction is usually negligible [3]. Thus the strength does not change appreciably from its existing value, and

[1] A. Casagrande, "Research on the Atterberg Limits of Soils." *Public Roads*, vol. 13. No. 8, p. 121 (October 1922).

[2] *See* Appendix I.

[3] In the present case a rough calculation has shown that there was an increase in bearing capacity of about 5–10 per cent., due to consolidation during the period of construction.

this is the value measured by testing undisturbed samples of the clay. Any errors implicit in the assumption are on the side of safety, since they involve an underestimate of the shear strength.

The methods of calculation, as described below, cannot be applied to soils for which the assumption is not valid, such as sands and very silty clays.

Notation.—

q	denotes	gross pressure on clay at foundation-level sufficient to cause a shear failure in the clay;
γ	"	density of clay;
H	"	depth of foundation-level;
γH	"	overburden pressure at foundation-level;
$q_0 = q - \gamma H$	"	ultimate bearing capacity of clay: the net increase in pressure sufficient to cause a shear failure in the clay;
s	"	shear strength of clay.

A. *Methods of Bell and Terzaghi.*—One of the first methods of calculating the bearing capacity of clay soils was developed by Mr. A. Langtry Bell, M. Inst. C.E.[1]. This method, when based on the above-mentioned assumption of no change in strength, shows that the clay will fail when

$$q - \gamma H = 4s \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

In the present investigation the shear strength of the clay below the footing was about 350 lb. per square foot and hence, from equation (1), the bearing capacity is calculated to be 1,400 lb. per square foot. This is a very considerable underestimate of the actual bearing capacity, the most probable value of which, as already stated, is about 2,500 lb. per square foot.

One reason for this method leading to an underestimate is that no account has been taken of the shear strength of the clay above foundation-level. This will increase the bearing capacity by resisting upward displacement of clay adjacent to the footing, and also by supplying friction along the sides of the footing.

An estimate of the full influence of these effects, for a strip footing, is included in a simplified analysis due to Terzaghi. This has been recently described by Mr. Guthlac Wilson, M. Inst. C.E.[2], and will not be emphasized here since it is intended primarily for demonstration purposes. It is, however, interesting to find that the result given by Terzaghi's method is

[1] A. L. Bell, "The Lateral Pressure and Resistance of Clay and the Supporting Power of Clay Foundations." Min. Proc. Inst. C.E., vol. xcxix (Session 1914–15), Part 1, p. 233.

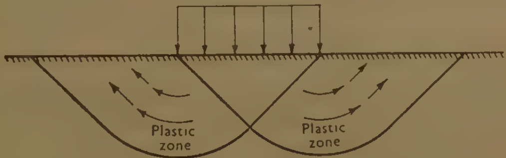
[2] Guthlac Wilson, "The Calculation of the Bearing Capacity of Footings on Clay." Journal Inst. C.E., vol. 17 (1941–42), p. 87 (Nov. 1941).

2,300 lb. per square foot, which is only slightly less than the actual bearing capacity.

B. *Methods of Prandtl and Hencky.*—That Bell's method should give a low result was not unexpected. Laboratory tests [1] on model footings founded on the surface of a clay have indicated that instead of the bearing capacity being $4s$, as given by equation (1), it ranged from $5s$ to $6{\cdot}5s$. These values are in closer agreement with the solutions [2] obtained from the theory of plasticity by Professor L. Prandtl and Dr. H. Hencky.

In the two-dimensional case of a material loaded on its surface with a long strip footing, Prandtl [3] assumes that failure takes place by a wedge of the material being pushed down and forcing the material on either side to flow outwards along the directions of the arrows in *Fig. 4* [4]. He

Fig. 4.



PRANDTL'S ANALYSIS OF STABILITY.

then analyses the stability of the system and finds that the pressure causing failure is

$$q_0 = (2 + \pi)s = 5{\cdot}14s \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

With an almost identical assumption of the mechanism of failure Hencky [5] has solved the problem for a rigid circular footing, and in this case he finds that failure occurs when

$$q_0 = 5{\cdot}64s \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Unfortunately the Prandtl-Hencky analysis has not been extended to footings below the surface, and approximations must therefore be made.

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[1] H. Q. Golder, "The Ultimate Bearing Pressure of Rectangular Footings." Journal Inst. C.E., vol. 17 (1941–42), p. 161 (Dec. 1941).

[2] Their application was suggested by Dr. L. Jurgenson, "The Application of Theories of Elasticity and Plasticity to Foundation Problems." Journal Boston Soc. C.E., vol. 21, No. 3, p. 206 (July 1934).

[3] L. Prandtl, "*Über die Härte plastischer Körper.*" *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen. Math-phys. Klasse* 1920, p. 74. Berlin, 1920.

[4] Observations of the behaviour of clay when loaded in a glass-fronted box show that this is a reasonable picture of the mechanism of failure.

[5] H. Hencky, "*Über einige statisch-bestimmte Fälle des Gleichgewichts in plastischen Körpen.*" *Zeit. Ang. Math. Mech.*, vol. 3, No. 4, p. 241 (Aug. 1923).

A lower limit can be found by neglecting the shear strength of the over-burden ; thus for a circular footing :—

$$q - \gamma H = 5{\cdot}64s \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3\text{A})$$

If it be granted that a circular footing is a sufficiently accurate repre-sentation of the 8-foot by 9-foot footing, the lower limit of the bearing capacity, as given by equation (3A), is 2,000 lb. per square foot.

For circular or rectangular footings the Author does not know of any published method of allowing for the increase in bearing capacity due to the shear strength of the clay above foundation-level. As a rough estimate it may, however, be suggested that the bearing capacity is increased by the full frictional resistance which can be developed along the sides of the footing. This is not an upper limit, but it is probably the maximum increase which would be allowed in design. Hencky's equation is therefore modified to the form :

$$q - \gamma H = 5{\cdot}64s + \frac{F}{A}s' \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where, in addition to the previous notation, F denotes the area of the side of the footing in contact with clay of shear strength s' and A denotes the area of the base. The base area is 72 square feet, the side area is 85 square feet, and s' is about 550 lb per square foot. By equation (4) the bearing capacity is therefore 2,600 lb. per square foot ; a result which is in reasonable agreement with the actual bearing capacity.

C. *Method of Fellenius.*—Owing to the variations which commonly exist in soil strata, graphical methods of analysis have been found in genera[l] to be of considerable value in the consideration of problems relating to th[e] stability of footings, owing to the fact that they are adaptable to comple[x] soil conditions. Indeed, in the present case, if the strength of the cla[y] below the footing had shown a greater variation it would have bee[n] difficult to decide upon a representative value for use in the foregoin[g] methods of analysis.

A simple graphical method for a strip footing can be obtained b[y] assuming that the clay will fail by shearing along a cylindrical arc, such a[s] that shown in *Fig. 5*. This was first suggested by Professor W. Fellenius [1] but he applied the method only to surface footings. It is interesting tha[t] he found that $q_0 = 5{\cdot}52s$, a result very similar to that of Prandtl, and al[so] in agreement with the laboratory tests [2]. The extension to footin[gs] below the surface, with a homogeneous clay, has been analysed b[y] Mr. Guthlac Wilson, and for details and principles of the method referen[ce] should be made to his Paper [3].

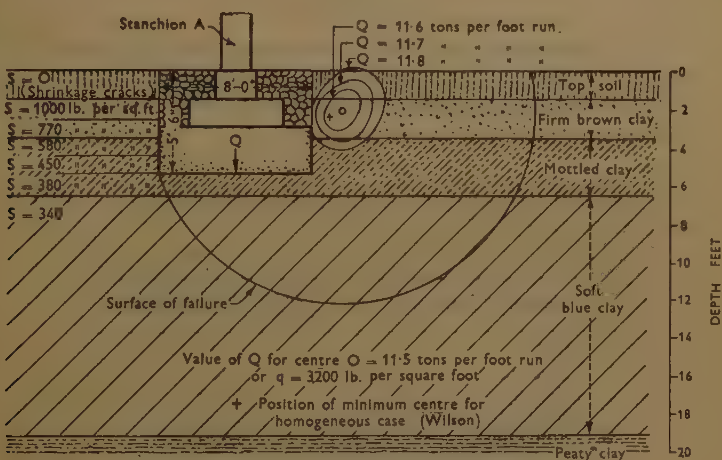
[1] W. Fellenius, "*Jordstatiska Beräkningar för vertikal Belastning på horison[tal] Mark under Antagande av circulärcylindriska Glidytor.*" *Teknisk Tidskrift*, vol. [...] No. 21, p. 57 (25 May, 1929).

[2] H. Q. Golder, *loc. cit.*

[3] G. Wilson, *loc. cit.*

In the present case of a non-homogeneous clay the following trial and error procedure was adopted. With any chosen centre [1] an arc was drawn and the average shear strength along the arc was then calculated by taking the clay as uniform over small strips, as shown in *Fig. 5*. Considering a section of unit thickness, the load necessary to apply the full shear strength along the arc was then found by taking moments about the centre. This was repeated for different centres until the minimum value of the footing load was obtained. The results are expressed in *Fig. 5* as a set of loci of centres giving equal values of the footing load: the minimum value is 11·5 tons per foot run. The footing is 8 feet wide and

Fig. 5.



RESULTS OF FELLENIUS' ANALYSIS.

the corresponding pressure is 3,200 lb per square foot. This is the gross pressure q and the bearing capacity $(q - \gamma H)$ is therefore (3,200–600) = 2,600 lb. per square foot—a result which compares well with the actual bearing capacity.

Method of Krey.—Another, and earlier, graphical method was developed by Professor H. Krey [2]. This was applied by Krey to shallow footings, and Wilson [3] has shown that, for footings at depths greater than about one-half their width, the bearing capacity, according to this method, is less than at the surface. The extension of Krey's method to such footings

[1] The first centre could conveniently be taken as that given by Wilson for the homogeneous case, since it is seen from *Fig. 5* that this is close to the minimum centre found by trial and error for the actual conditions of a variable clay.

[2] H. Krey, "*Erddruck, Erdwiderstand, und Tragfähigkeit des Baugrundes*", p. 163. Berlin, 1926.

[3] G. Wilson, *loc. cit.*

is therefore not advisable. For this reason the method is not considere here in any detail; but since the effect of decreasing bearing capacity i not serious for the conditions of the present investigation, it is of interes to note in passing that the method gives a result of 2,100 lb per square foot which is some indication that the method is probably reliable when applie within its range of validity.

Summary and Conclusions.

During the construction of a building the clay beneath the mos heavily loaded footing failed in shear, and considerable damage wa caused. The footing was 8 feet by 9 feet in plan and was founded at a depth of 5½ feet below ground-level. From the load on the footing at th time of failure it was deduced that the ultimate bearing capacity of th clay was about 2,500 lb. per square foot. Tests on undisturbed sample showed that the shear strength of the clay below the footing was abou 350 lb. per square foot, and above foundation-level was about 550 lb. pe square foot.

Using these test data, the bearing capacity was then calculated by th following methods :—

Method of analysis.		Calculated ultimate bearing capacity : lb. per sq. ft.
A.	Bell	1,400
	Terzaghi	2,300
B.	Hencky	2,000
	Hencky, modified .	2,600
C.	Fellenius	2,600

A comparison of these results with the actual bearing capacity lead to the following conclusions, valid only for the conditions of this investi gation :

(1) The methods of Bell and Hencky, which make no allowance fo the shear strength of the clay above foundation-level, ar conservative; Bell's method being unduly conservative.

(2) The methods of Fellenius, of Terzaghi, and of Hencky, whe modified to allow for friction on the sides of the footing, ar of adequate practical reliability.

Acknowledgements.

The work described was carried out at the Building Research Statio of the Department of Scientific and Industrial Research, and the result are published with the permission of the Director of Building Research.

The Author wishes to acknowledge the assistance he received in the field work from his colleague, Mr. J. S. Button.

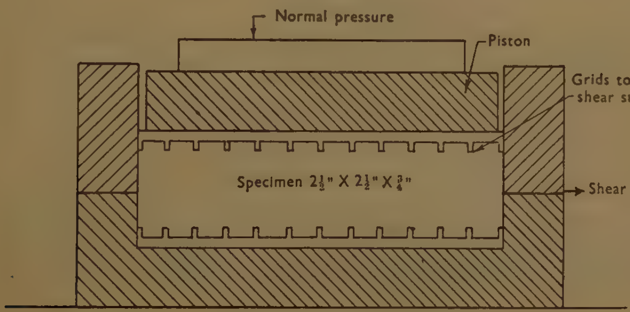
The Paper is accompanied by six sheets of drawings from which the Figures in the text have been prepared.

APPENDIX I.

Relation between Consolidation and Shear Strength.

Terzaghi [1], Jürgenson [2], and others have shown that a clay can gain in strength under an applied pressure only if consolidation is allowed to occur. This was demon-

Fig. 6.



Sketch of Shearbox.

strated for the blue clay in the following simple experiment. Three specimens of the clay were placed in the standard shear box apparatus shown in *Fig. 6*, under different vertical pressures. Immediately after applying this pressure the shear strength was determined by measuring the horizontal force required to pull off the top half of the box. The vertical pressure was therefore normal to the shear plane; and the relation between normal pressure and shear strength is shown in *Fig. 7*. Water-content determinations of the clay before and after test showed that there had been no consolidation, and it will be seen that there was no increase in strength. This is known as the "immediate shear test."

The experiment was then repeated, but the specimens were placed between porous stones and the vertical pressures were maintained for 24 hours before carrying out the shear test. In this way the clay was able fully to consolidate under the pressure, and it will be seen that under the higher two pressures there was a considerable increase

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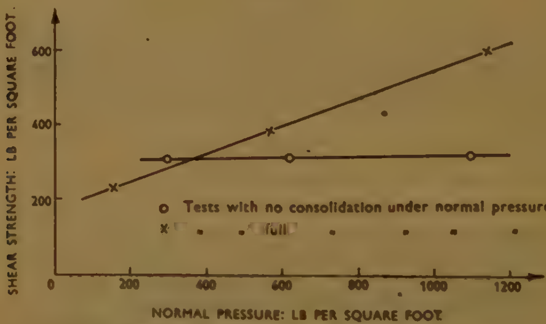
[1] K. Terzaghi, "*Tragfähigkeit der Flachgründungen*", Int. Assoc. Bridge Struct. Eng., p. 659. Paris, 1932.

[2] L. Jürgenson, "The Shearing Resistance of Soils", Journal Boston Soc. C.E., vol. 21, No. 3, p. 242 (July 1934).

in strength. Under the lowest pressure there was a slight swelling of the clay, as would be expected since this pressure was lower than the original overburden pressure on the clay when in the ground, and the strength was reduced. This is known as the "equilibrium shear test."

The rate of consolidation of the main body of clay below the footing was very much lower than in the test specimens, owing to the greater distance which the pore-water had to travel before reaching a drainage surface. In the equilibrium shear test it was found that 25 per cent. of the consolidation was completed within 5 minutes after application of the pressure; and, using this result, a rough calculation, based on Terzaghi's theory of consolidation [1], showed that a similar degree of consolidation in the clay 3 feet below the footing would be completed after 5 months. This calculation was made on the assumption that the concrete of the footing was very permeable. It is therefore probable that more than 5 months would be required; and it is certain

Fig. 7.



SHEAR TESTS ON BLUE CLAY: DEPTH 8 FEET.

that the clay in the region marked "plastic zone" in *Fig. 4* would consolidate at a very considerably lower rate. It can then be readily seen that no consolidation can be depended upon during the period of construction.

APPENDIX II.

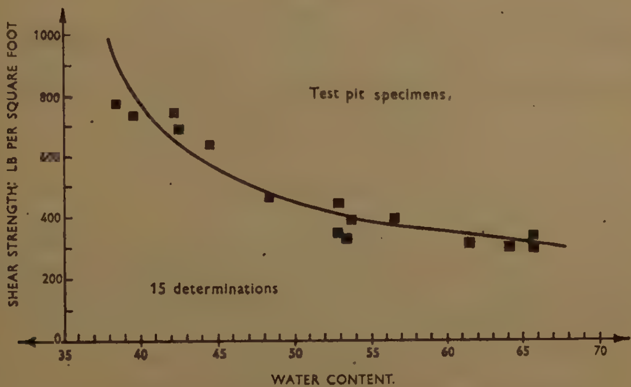
RELATION BETWEEN SHEAR AND COMPRESSION STRENGTH.

On p. 311, *ante*, it is stated that the shear strength of a clay is equal to one-half its compression strength. In order to check this relation for the clays in the present investigation, a series of immediate shear and compression tests were carried out on samples from the test-pit. The results are given in *Figs. 8* and *9*, and it will be seen that at any particular water-content the relation is roughly correct. This is also established in *Figs. 3 (b)*, wherein the shear strength, and one-half the compression strength, are plotted against depth and are found to lie on the same curve.

[1] K. Terzaghi and O. K. Fröhlich, "*Theorie der Setzung von Tonschichten*", p. 50. Vienna, 1936.

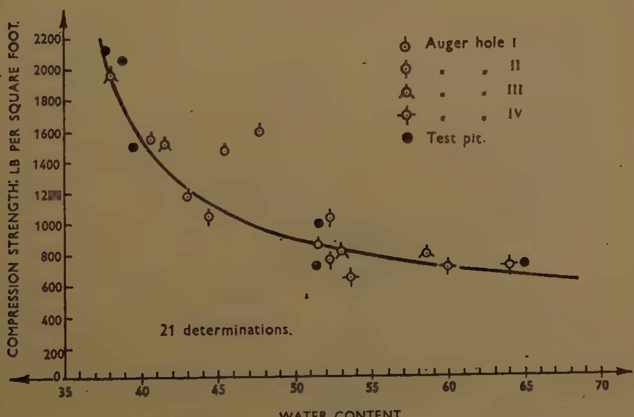
The theoretical reason for this relationship is that in the compression test, as in the immediate shear test, no consolidation of the clay occurs; therefore the shear resistance along any plane in a loaded mass of clay is independent of the normal pressure acting on that plane. In this respect it differs from a frictional material

Fig. 8.



RELATION BETWEEN SHEAR STRENGTH AND WATER CONTENT.

Fig. 9.



RELATION BETWEEN COMPRESSION STRENGTH AND WATER CONTENT.

such as a sand or very silty clay or an ordinary clay which is allowed to consolidate. Because the resistance is the same along all planes, and is the shear strength of the clay, it follows that failure will occur along the plane of maximum shear stress when this stress becomes equal to the shear strength. Now the maximum shear stress in a cylinder subjected to an axial pressure p is $p/2$ and acts on a plane inclined at 45 degrees to the axis: therefore failure will occur when $p/2=s$: or, in other words, the shear strength is equal to half the compression strength.

Paper No. 5308.

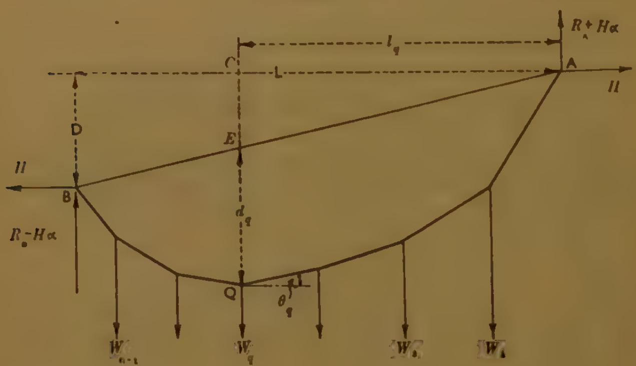
"The Stresses in an Extensible Suspension Cable."

By Professor ALFRED JOHN SUTTON PIPPARD, M.B.E., D.Sc., M. Inst. C.E., and LETITIA CHITTY, M.A.

(Ordered by the Council to be published with written discussion.)[1]

IT is customary in most calculations connected with suspension systems to assume that the cable is inextensible, but if the dips are small this may introduce serious errors. During the recent investigation by the Authors of a structure of this type, certain formulas were developed which allow the elastic stretch of the cable to be taken into account. These appear to

Fig. 1.



be in a useful form not hitherto published, and they are given in this Paper.

Fig. 1 shows a cable, of weight supposed to be negligible in comparison with the loads which it carries, supported at points A and B which are separated by a horizontal distance L and a vertical distance D.

Assume the loads on the cable to be $W_1, W_2, \ldots W_q, \ldots W_{n-1}$ acting at distances $l_1, l_2, \ldots l_q \ldots l_{n-1}$ from A, measured horizontally

[1] Correspondence on this Paper can be accepted until the 15th August 1942, and will be published in the Institution Journal for October 1942. Contributions should be limited to 300 words.—SEC. INST. C.E.

to their final lines of action; and the reactions at A and B due to these loads to be $R_A + H\alpha$ and $R_B - H\alpha$ vertically, and H horizontally, where H denotes the constant horizontal component of tension in the cable and α is written for D/L.

Denoting by S, the original length of the cable before it is placed in position between the supports A and B;
- d_q, the dip at the load point Q when the cable is loaded, measured from the line AB;
- θ_q, the angle between the cable in the qth bay and the horizontal;
- A, the cross-sectional area of the cable;
- E, Young's modulus for the material of the cable;
- M_q, the bending moment at the qth load due to the force system if H is assumed to be zero;
- F_q, the vertical shearing force in the qth bay on the same assumption;

then taking moments about Q gives

$$(d_q + EC)H - H\alpha l_q - M_q = 0;$$

and since $EC = \alpha l_q$,

$$d_q = \frac{M_q}{H} \quad \ldots\ldots\ldots\ldots \quad (1)$$

Also,
$$\tan\theta_q = \frac{(d_q + \alpha l_q) - (d_{q-1} + \alpha l_{q-1})}{l_q - l_{q-1}} = \frac{M_q - M_{q-1}}{H(l_q - l_{q-1})} + \alpha;$$

but
$$\frac{M_q - M_{q-1}}{l_q - l_{q-1}} = F_q,$$

and so,
$$\tan\theta_q = \frac{F_q}{H} + \alpha \quad \ldots\ldots\ldots \quad (2)$$

then, if θ_q is not too large,

$$\sec\theta_q = 1 + \tfrac{1}{2}\left(\frac{F_q}{H} + \alpha\right)^2 \quad \ldots\ldots\ldots \quad (3)$$

Subsequent results are based upon this approximation for sec θ_q, and their application should, therefore, be limited to cases in which the maximum slope of the loaded cable is comparatively small. Table I gives the error involved for different values of θ; even when $\theta = 30$ degrees it is only about 1 per cent., but it increases rapidly for larger values and the results become increasingly inaccurate. The useful range is, however, considerable and probably covers most cases of cables used for structural purposes.

TABLE I.

θ.	Tan θ.	Sec θ. Accurate.	Sec θ. Approximate.	Error: per cent.
0	0	1	1	0
10	0·1763	1·0154	1·0155	0·01
20	0·3639	1·0642	1·0662	0·19
30	0·5773	1·1547	1·1667	1·04
45	1·0	1·4142	1·5000	6·07
60	1·7320	2·0	2·5	25·0

The strained length of the cable in the qth bay is $(l_q - l_{q-1}) \sec \theta_q$, and so the total length of the cable is,

$$\sum_1^n (l_q - l_{q-1})\left\{1 + \tfrac{1}{2}\left(\frac{F_q}{H} + \alpha\right)^2\right\}$$

$$= (1 + \tfrac{1}{2}\alpha^2)\sum_1^n (l_q - l_{q-1}) + \frac{1}{2H^2}\sum_1^n (l_q - l_{q-1})F_q^2 + \frac{\alpha}{H}\sum_1^n (l_q - l_{q-1})F_q.$$

Now from equation (2),

$$\sum_1^n (l_q - l_{q-1}) \tan \theta_q = \frac{1}{H}\sum_1^n (l_q - l_{q-1})F_q + \alpha\sum_1^n (l_q - l_{q-1})$$

or,

$$D = \frac{1}{H}\sum_1^n (l_q - l_{q-1})F_q + D;$$

so

$$\sum_1^n (l_q - l_{q-1})F_q = 0.$$

The total strained length of the cable is, therefore,

$$L(1 + \tfrac{1}{2}\alpha^2) + \frac{Z}{2H^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

where

$$Z = \sum_1^n (l_q - l_{q-1})F_q^2.$$

Now if T_q denote the tension in the cable in the qth bay, the increase in its length in this bay is

$$\frac{T_q(l_q - l_{q-1}) \sec \theta_q}{AE},$$

and since $T_q = H \sec \theta_q$, the total increase in the length of the cable is

$$\frac{H}{AE}\sum_1^n (l_q - l_{q-1}) \sec^2 \theta_q,$$

and the strained length is, using equation (3),

$$S + \frac{H}{AE}\left[L(1+\alpha^2) + \frac{Z}{H^2}\right]. \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Equating (4) and (5) gives

$$2H^3L(1+\alpha^2) + 2H^2AE\{S - L(1+\tfrac{1}{2}\alpha^2)\} + Z(2H - AE) = 0.$$

Since AE is very large in comparison with H, this becomes, very nearly,

$$2H^3L(1+\alpha^2) + 2H^2AE\{S - L(1+\tfrac{1}{2}\alpha^2)\} - ZAE = 0 \quad . \quad (6)$$

This equation determines H for any specified length of cable and distribution of load.

If the cable is inextensible, AE is infinite, and equation (6) gives

$$H^2 = \frac{Z}{2\{S - L(1+\tfrac{1}{2}\alpha^2)\}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Generally, equation (6) for the extensible cable is best solved by trial, whilst equation (7) is a good first approximation to the correct answer when the cable has a fair sag before the loads are applied.

If, on the other hand, the cable is erected with an initial tension whose horizontal component is H_0, then

$$L(1+\tfrac{1}{2}\alpha^2) = S\left\{1 + \frac{H_0(1+\frac{1}{2}\alpha^2)}{AE}\right\},$$

and on substituting the value obtained for S from this, equation (6) becomes

$$2L(1+\alpha^2)(H^3 - H^2H_0) - ZAE = 0 \quad . \quad . \quad . \quad . \quad (8)$$

where H denotes the final tension under load.

If the cable is extensible and is stretched between the supports so that it may be taken to be initially straight, but with no initial tension, $S = L(1+\frac{1}{2}\alpha^2)$, and equation (6) gives

$$H^3 = \frac{AE\sum_1^n (l_q - l_{q-1})F_q^2}{2L(1+\alpha^2)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Some particular forms of this result may be noted.

(*a*) If the loads are unequal, but are spaced equally along the span that is if $l_q - l_{q-1} = l$,

$$H^3 = \frac{AE}{2n(1+\alpha^2)}\sum_1^n F_q^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

where n denotes the number of equal bays in the cable.

(*b*) If the loads and spacings are both equal, that is, if $l_q - l_{q-1} =$ and $W_1 = \ldots = W_q = \ldots = W_{n-1} = \ldots = W$,

$$\sum_1^n F_q^2 = \frac{W^2 n(n^2-1)}{12},$$

and

$$H^3 = \frac{AEW^2(n^2-1)}{24(1+\alpha^2)} \quad . \quad . \quad . \quad . \quad . \quad (11)$$

(*c*) If the loads and spacings are both equal and A and B are at th same level, that is, if $D = 0$,

$$H^3 = \frac{AEW^2(n^2-1)}{24} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

(*d*) If the loading is continuous and of uniform intensity w along AB the shearing force at a distance x from A is $w(\frac{1}{2}L - x)(1 + \frac{1}{2}\alpha^2)$.

Then,

$$Z = w^2(1+\alpha^2)\int_0^L (\tfrac{1}{2}L - x)^2 dx = \frac{w^2L^3(1+\alpha^2)}{12},$$

and

$$H^3 = \frac{AEw^2L^2}{24} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

(*e*) If the loading is continuous and the supports are at the same leve again, as in case (*d*),

$$H^3 = \frac{AEw^2L^2}{24} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

In the particular case of the inextensible cable loaded uniformly, th supports being at the same level, equation (7) becomes

$$H^2 = \frac{w^2L^3}{24(S-L)}.$$

In this case the length of the cable is $L\left(1 + \frac{8d^2}{3L^2}\right)$, using the same degre of approximation for sec θ as before, so that

$$H = \frac{wL^2}{8d},$$

which is a well-known result obtainable directly from equation (1).

In all cases, when H has been calculated, the dips may be found from equation (1) and the loaded shape of the cable thus determined.

As an example of the use of the foregoing formulas, consider the case of a cable stretched tightly between two points A and B which are 100 feet apart horizontally, A being 10 feet above B so that $\alpha = 0 \cdot 1$. The loads are 2 tons, 1 ton, $\frac{1}{2}$ ton, $\frac{1}{2}$ ton, and 1 ton acting at distances of 20 feet, 30 feet, 50 feet, 80 feet, and 90 feet respectively from A. The value of AE is 6,000 tons.

If the loads are assumed to act upon a beam of 100 feet span the reaction at A is 2·75 tons. The shearing forces and bending moments at the load points are calculated and entered in columns (3) and (6) of Table II. The values of $l_q - l_{q-1}$ are entered in column (2), and calculated values of F_q^2 and $(l_q - l_q{}^{-}{}_1)F_q^2$ in columns (4) and (5). The sum of the values in column (5) gives $Z = 241$ foot-tons², and H is then found from equation (9) to be 19·3 tons. The dips are found by dividing the bending moments in column (6) by H, and are given in column (7):

TABLE II.

1	2	3	4	5	6	7
Point.	$l_q - l_{q-1}$.	F_q.	F_q^2.	$(l_q - l_{q-1})F_q^2$.	M_q.	d_q.
A					0	0
	20	2·75	7·56	151·2		
C					55	2·85
	10	0·75	0·56	5·6		
D					62·5	3·24
	20	− 0·25	0·06	1·2		
E					57·5	2·98
	30	− 0·75	0·56	16·8		
F					35·0	1·81
	10	− 1·25	1·56	15·6		
G					22·5	1·17
	10	− 2·25	5·06	50·6		
B					0	0

A problem that arises in design is to determine the size of cable required to carry a given load system with a specified sag and with a given factor of safety. The results obtained enable this to be done, but it is advisable to modify the earlier assumptions in one particular. It has been assumed, in the previous analysis, that the weight of the cable could be neglected; but since it is necessary, for the present purpose, to know the initial tension in it, this factor will now be introduced. Also, the sag-to-span ratio affords the most practical method of specifying the initial tension and is the simplest measurement which ensures that the required tension has been given.

Let w_0 denote the weight of the cable per unit length ;
d_0, the maximum sag in the unloaded cable ;
H_0, the initial horizontal tension in the cable ;
H, the horizontal tension in the fully-loaded cable ;
N, the required factor of safety ;
d_P, the specified final sag in the loaded cable at any point P, wher[e] the bending moment, as defined on p. 323, *ante*, is M_P ;
and f_u, the ultimate stress of the material of the cable.

Other symbols have the same significance as in earlier paragraphs, an[d] *Fig. 1* may be taken to represent the conditions of the problem.

From equation (1), $$H = \frac{M_P}{d_P},$$

and as small sag-to-span ratios are alone considered,

$$A = \frac{NH(1 + \frac{1}{2}\alpha^2)}{f_u} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

which determines the necessary area of the cable, and so the value of w_0

Then, $$H_0 = \frac{w_0 L^2(1 + \frac{1}{2}\alpha^2)}{8d_0}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

where d_0 is unknown and has to be determined.

The length of the cable under its own weight is

$$L(1 + \tfrac{1}{2}\alpha^2)\left\{1 + \frac{8d_0^2}{3L^2(1 + \frac{1}{2}\alpha^2)}\right\}. \quad . \quad . \quad . \quad . \quad (17)$$

Also, if S denote the original unstrained length of the cable, its lengt[h] under the action of its own weight is

$$S\left\{1 + \frac{H_0(1 + \frac{1}{2}\alpha^2)}{AE}\right\}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

Equating (17) and (18) leads to

$$\Delta = \frac{8d_0^2}{3L} - \frac{H_0 L(1 + \alpha^2)}{AE} \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

where $\Delta = S - L(1 + \frac{1}{2}\alpha^2)$, that is, the excess length of the unstraine[d] cable over the distance which it has to span.

When the cable is fully loaded its strained length is, from equation (4),

$$S - \Delta + \frac{Z}{2H^2};$$

therefore the increase in length of the cable when fully loaded is

$$e = \frac{Z}{2H^2} - \Delta,$$

or, from equation (19), $e = \frac{Z}{2H^2} + \frac{H_0L(1+\alpha^2)}{AE} - \frac{8d_0^2}{3L}$.

The final stress in the cable is then Ee/S. It is also f_u/N, so

$$\frac{f_u}{N} = \frac{1}{S}\left\{\frac{ZE}{2H^2} + \frac{H_0L(1+\alpha^2)}{A} - \frac{8d_0^2E}{3L}\right\}$$

By substituting $S = L(1 + \frac{1}{2}\alpha^2) + \varDelta$, and neglecting obviously small terms, the expression

$$d_0^3 + \tfrac{3}{8}d_0\left\{\frac{L^2(1+\frac{1}{2}\alpha^2)f_u}{NE} - \frac{ZL}{2H^2}\right\} - \frac{3\rho L^4(1+\frac{3}{2}\alpha^2)}{64E} = 0 \quad . \quad (20)$$

is obtained, where ρ denotes the density of the material.

This determines the value of d_0 required to satisfy the specified conditions; H_0 and $\varDelta$ are then found from equations (16) and (19) respectively. In this analysis the contribution of the weight of the cable to the bending moment at P has been neglected as being generally very small, but it may be included as follows. The extra bending moment at P due to w_0 can be written as βw_0, where β depends only upon the position of P, and introducing the density of the material of the cable, this becomes $\beta\rho A$.

Then, $$H = \frac{M_P + \beta\rho A}{d_P} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (21)$$

On substituting this value of H in equation (15), a more accurate value of A is found to be

$$A = \frac{M_P}{\frac{f_u d_P}{N(1+\frac{1}{2}\alpha^2)} - \beta\rho} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

The remainder of the analysis is as before, but the value of Z should now strictly include the contribution from the cable weight.

As an example of the use of these formulas, the case dealt with on p. 327, *ante*, is re-calculated from the point of view of design. It is required, say, to determine the size of cable needed to carry the load system specified over the span of 100 feet with a load factor of 4·75 and a sag of 3·24 feet at a point 30 feet from A. The value of E for stranded cable is 6,500 tons per square inch, and the ultimate stress is 100 tons per square inch. The difference of level between the supports is 10 feet, so that $\alpha = 0{\cdot}1$. These data are consistent with the conditions of the previous example, except that the weight of the cable is taken into account

Now $$H = \frac{M_D}{d_D} = \frac{62{\cdot}50}{3{\cdot}24} = 19{\cdot}3 \text{ tons},$$

the value of M_D being taken from Table II.

From equation (15),

$$A = \frac{4{\cdot}75 \times 19{\cdot}3 \times 1{\cdot}005}{100} = 0{\cdot}92 \text{ square inch,}$$

so $$w_0 = 0{\cdot}92 \times 0{\cdot}28 \times 12 = 3{\cdot}1 \text{ lb. per foot,}$$

taking the density of the cable as 0·28 lb. per cubic inch.

Taking the value of Z from Table II, equation (20) gives

$$d_0{}^3 + 0{\cdot}075 d_0 - 1{\cdot}10 = 0.$$

from which $$d_0 = 1{\cdot}01 \text{ foot.}$$

from equation (16)

$$H_0 = \frac{3{\cdot}1 \times 100 \times 100{\cdot}5}{8 \times 1{\cdot}01 \times 2{,}240} = 1{\cdot}7 \text{ ton.}$$

The initial stress is therefore $1{\cdot}7/0{\cdot}92 = 1{\cdot}85$ ton per square inch, an from equation (19), $\Delta = -0{\cdot}0022$ foot, or $-0{\cdot}026$ inch. This is negligible and the cable must therefore be initially the same length as the distanc between supports. The only initial tension is due to sag under its ow weight.

Suppose, however, that it is desired to reduce the sag in the loade cable to 2·0 feet, and also to reduce the load factor to 3·0, all other con ditions being the same as before :

then, $$H = \frac{62{\cdot}5}{2{\cdot}0} = 31{\cdot}25 \text{ tons,}$$

and $$A = \frac{3 \times 31{\cdot}25 \times 1{\cdot}005}{100} = 0{\cdot}94 \text{ square inch.}$$

so that $$w_0 = 0{\cdot}94 \times 0{\cdot}28 \times 12 = 3{\cdot}16 \text{ lb. per foot.}$$

Then equation (20) gives

$$d_0{}^3 + 14{\cdot}7 d_0 - 1{\cdot}10 = 0$$

or, $$d = 0{\cdot}075 \text{ foot, or } 0{\cdot}9 \text{ inch.}$$

Then, $H = 23{\cdot}6$ tons, the initial stress $= 25$ tons per square inch, an $\Delta = -0{\cdot}39$ foot, or $-4{\cdot}7$ inches.

This initial shortening is additional to any that may be necessary t take out the inelastic stretch which is typical of most stranded cables.

In these calculations the weight of the cable has been neglected a regards its effect upon the bending moments and upon Z ; to take it int account equation (22) is used instead of equation (15), and the followin modified results are obtained for the first example above.

It is necessary to keep all units consistent, so

$$M_D = 62{\cdot}5 \times 2{,}240 \text{ foot-lb.};$$

$$f_u = 100 \times 144 \times 2{,}240 \text{ lb. per square foot};$$

$$d_D = 3{\cdot}24 \text{ feet};$$

and the bending moment at D due to $w_0 = \frac{1}{2}w_0(1 + \frac{1}{2}\alpha^2) \times 30 \times 70 = 1{,}055\ w_0$ foot-lb.;

therefore $\beta = 1{,}055$ feet-units,

and $\rho = 0{\cdot}28 \times 1{,}728$ lb. per cubic foot.

Then, substituting in equation (22),

$$\Delta = 0{\cdot}00655 \text{ square foot} = 0{\cdot}945 \text{ square inch};$$

so that $w_0 = 0{\cdot}945 \times 0{\cdot}28 \times 12 = 3{\cdot}18$ lb. per foot.

The value Z from Table II will be increased by the term

$$\frac{w_0^2L^3(1 + \alpha^2)}{12},$$

as shown in paragraph (*d*), on p. 326, *ante*, but the addition is so small that it can be neglected: d_0 is therefore the same as before

In the foregoing the stresses and loaded configuration of a cable have been determined on the assumption that the cable is negligible in weight. It may be convenient to take the weight into account, and the necessary formulas are therefore developed as follows. It is, however, still assumed that the individual bays of the loaded system are appreciably straight between load points.

As before, denote the original length of the cable by S and its weight by w_0 per unit length. Also, let $S - L(1 + \frac{1}{2}\alpha^2) = \Delta$, and assume that the value of Δ is known.

Then from equation (19), $\dfrac{8d_0^2}{3L} = \dfrac{H_0L(1 + \alpha^2)}{AE} + \Delta,$

and by substituting for d_0 from equation (16),

$$H_0^3 + H_0^2\frac{\Delta AE}{L(1 + \alpha^2)} - \frac{w_0^2L^2AE}{24} = 0, \quad . \quad . \quad . \quad (23)$$

which determines H_0.

Then in equation (8), on extending the term for Z to include the value due to the weight of the cable, as found on p. 326, *ante*,

$$2L(1 + \alpha^2)(H^3 - H_0H^2) - AE\left(Z + \frac{w_0^2L^3(1 + \alpha^2)}{12}\right) = 0, \quad . \quad (24)$$

which determines H.

Then $$d_q = \frac{M_q + \beta_q w_0}{H} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (25)$$

where β_q denotes the value of β as defined on p. 329, *ante*, for the point Q that is, $\frac{1}{2}l_q(L - l_q)(1 + \frac{1}{2}\alpha^2)$.

Hence the sags at all points on the cable can be found.

Simple experiments were made upon a piano-wire stretched between two points separated horizontally by a distance of 13 feet 9 inches and vertically by 1 foot 9 inches. The elastic behaviour of the wire was determined by loading a 13-foot length axially by hanging weights on it, the extensions produced being measured by a micrometer. A good straight line was obtained, from which the value of AE was found to be 9,360 lb.

In order to estimate the initial tension in the suspension wire, a range of loads was applied at a point 9 feet 4 inches from the higher support and the resulting dips at that point were measured. Equations (8) and (1 were then used to deduce a value for H_0 which would give agreement between the experimental and calculated load-displacement curves. A value of $H_0 = 7{\cdot}5$ lb. was found to give practically exact agreement, as shown in Table III.

TABLE III.

Load : lb.	Deflexion : inches.	
	Measured.	Calculated.
0·3	1·3	1·25
0·55	2·0	1·9
1·3	3·15	3·1
2·3	4·1	4·1
3·3	4·75	4·75
4·3	5·3	5·3
5·3	5·75	5·75
6·3	6·15	6·15
8·3	6·85	6·85
10·3	7·4	7·4

Two experiments were then made by applying loads to six points the horizontal distances of which from the higher support are given in the first column of Table IV. The dips at these points were measured and they are compared in the last two columns with the theoretical values calculated on the assumption that $H_0 = 7{\cdot}5$ lb. It is evident that the agreement is very close.

TABLE IV.

Distance from support: inches.	Load: lb.	Deflexion: inches.	
		Measured.	Theoretical.
20	0·3	1·4	1·45
30	0·3	1·9	2·0
45	0·3	2·4	2·45
80	0·3	2·9	2·95
90	0·3	2·8	2·85
120	0·3	2·0	2·1
20	2·3	3·4	3·5
30	1·8	4·55	4·7
45	3·3	5·9	5·95
80	2·3	6·3	6·25
90	0·8	5·85	5·85
120	1·3	4·0	4·0

The Paper is accompanied by one diagram, from which the Figure in the text has been prepared.

INGENUITY COMPETITION, 1941.

"Temporary Storage of Structural Steel."

By ROBERT COWAN MACDONALD, M. Inst. C.E.

LIMITED space for the storage of materials is frequently a problem on large constructional contracts, and at times the engineer's ingenuity is severely taxed to store the materials in such a manner that time is not wasted by double handling when they are required for erection.

During the construction of a large bridge in the north of England the only available space for storing the steelwork for the superstructure, amounting to about 6,000 tons, was along the approaches. The space between the parapet walls was about 27 feet, and a service railway-line was laid on one side. The erection scheme provided for two 10-ton steam-cranes on each side of the river, one for the storage-ground and one for erection.

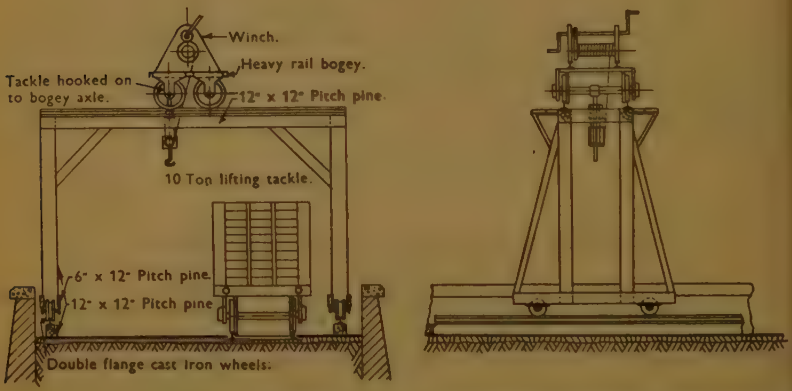
By arrangement with the Railway Company, fabricated sections of steelwork weighing up to 9 tons each were delivered in 40-ton coal-wagons, on the understanding that these wagons should not be detained on the site for more than 24 hours; failing this a very heavy demurrage charge would be imposed.

Owing to delays in transport, a 10-ton crane, which was being transferred from another contract and should have been in position to discharge the material, had not arrived when the invoice was received for the first

consignment, comprising a train of six of these wagons, containing 150 tons of steelwork. On receipt of the invoice the Author considered several methods of handling the steelwork, with derricks or shear legs, but had to reject them as being too slow.

The plant available included a number of heavy double-flanged cast-iron wheels 18 inches in diameter, each keyed to stout axles which projected on each side of the wheel: two plain cast-iron bearings were provided for each wheel. There were also available a good supply of 12-inch by 12-inch and 12-inch by 6-inch pitch pine, and of heavy-section flat-bottom rails, a heavy platelayer's bogie, a double-purchase hand winch, a 10-ton wire rope tackle, and numerous bolts and timber dogs. On the

Figs. 1.



basis of these materials the Author prepared a design (*Figs. 1*) for a timber gantry to span the space between the parapet walls.

The undercarriages for the gantry were made up of two 12-inch by 6-inch pitch-pine timbers; the plain bearings carrying the double-flanged wheels were bolted to the underside of the undercarriages. The vertical and cross members were compo ed of 12-inch by 12-inch timbers, and were set 5 feet apart, centre to centre, to allow for flat- bottom rails being set at 4-foot $8\frac{1}{2}$-inch gauge on the cross members, which were strutted with 12-inch by 6-inch timbers. The heavy rail bogie, on which the double-purchase winch was mounted, was set on the track on the cross members and the 10-ton tackle was suspended from one of the axles; the fall of the tackle was wound on the drum of the winch. A platform for operating the winch, composed of two 9-inch by 3-inch planks, was overhung from each side of the cross members.

Two hours after the receipt of the invoice the carpenters commenced the construction of this gantry. At the same time another squad started to lay 12-inch by 12-inch timbers alongside the parapet walls, and rai

were laid on these timbers to provide a track for the gantry. By working all night the carpenters had the gantry completed in time to start discharging the train when it arrived next morning. The first wagon in the train was run under the gantry; its contents were lifted out and laid alongside the service line. The gantry was then travelled over the next wagon, and so on until all were discharged well within the allotted time.

The Note is accompanied by one sheet of drawings, from which the Figure in the text has been prepared.

OBITUARY.

SIR WILLIAM HENRY BRAGG, O.M., K.B.E., F.R.S., was born at Stoneraise Place, Wigton, Cumberland, on the 2nd July 1862, and died in London on the 12th March 1942. He was educated at King William's College, Isle of Man, where he won a scholarship to Trinity College, Cambridge. After graduation he obtained an appointment as Professor of Physics and Mathematics at Adelaide University, and retained that position for 27 years. In 1909 he became Cavendish Professor at Leeds University, and from 1915 to 1923 was Quain Professor of Physics at London University. In 1920 he was elected an Honorary Fellow of Trinity College, Cambridge. His researches in the field of crystalline analysis and X-ray spectroscopy received world-wide recognition, and his work in collaboration with his elder son (now Sir Lawrence Bragg) gained for them the joint award of the Nobel Prize for Physics and the Barnard Gold Medal of Columbia University in 1915. Other distinctions included the Rumford Medal of the Royal Society (1916), the Gold Medal of the *Societá Italiana delle Scienze* (1917), the Copley Medal and the Franklin Gold Medal (1930), the Faraday Medal (1936), and the John Carly Medal of the U.S. National Academy of Science (1939). In 1931 he was awarded the Order of Merit. He received honorary degrees from many Universities, and was a member of the Academies of Denmark, Holland, Norway, Paris, Spain, Turin, and the United States. His numerous publications included contributions on radio-activity, crystal structures, and other scientific subjects.

During the war of 1914–1918 he was engaged in submarine detection and the anti-submarine campaign. He worked for the Admiralty at Aberdour in 1916 and at Harwich in 1917, returning to London as consultant to the Admiralty in 1918. His services were recognized by the award of the C.B.E. in 1916 and by his advancement to K.B.E. in 1920.

In 1923 he was appointed Fullerian Professor of Chemistry and Director of the Royal Institution, and also Director of the Davy-Faraday Laboratory. In 1935 he became President of the Royal Society, and in 1937 a member of the Advisory Council for Scientific and Industrial Research.

Sir William Bragg was elected an Honorary Member of The Institution on the 3rd November 1936. On the 27th April 1937, he delivered the Forty-third "James Forrest" Lecture, on "The Crystal and the Engineer [1]."

In 1889 he married Gwendoline, daughter of the late Sir Charles Todd, Postmaster-General and Astronomer-Royal, South Australia, and had two sons and one daughter. Lady Bragg died in 1929; their second son was killed at Gallipoli.

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[1] Journal Inst. C.E., vol. 6 (1936–37), p. 181 (June 1937).

REPORT OF THE COUNCIL, 1941–1942.

In accordance with the By-laws, the Council present the following report upon the state of The Institution.

Meetings.—Ordinary Meetings have been held throughout the Session at monthly intervals, and it has also proved possible to arrange meetings of the Road Engineering Section and the Railway Engineering Section. Two joint meetings with the Institutions of Mechanical and Electrical Engineers have taken place, one at the Central Hall, Westminster, and the other in the Great Hall of The Institution. It has been the Council's policy to promote, as far as practicable, the presentation of subjects of wide appeal which were related to the national war effort, and the Council have been much encouraged by the interest displayed in the meetings, by the good attendances, and by the high standard of the discussions.

The opening meeting of the Session was held on the 4th November, when Professor C. E. Inglis, O.B.E., M.A., LL.D., F.R.S., delivered his Presidential Address, which dealt with the subject of Engineering Education. The opinions expressed in the Address, emanating as they do from one having such long experience and intimate knowledge of university education, have commanded attention and will have a strong influence on any plans for the adaptation of engineering education to satisfy post-war needs—a matter now receiving much consideration. The Address has attracted interest not only in this country but also overseas, particularly in Canada and the United States.

The following is a list of the subjects dealt with at the Meetings :—

9 December (Jointly with the Institutions of Mechanical and Electrical Engineers) " Air-Raids Precaution Measures and the Engineering Industry "—

(*a*) " The Effect of High Explosives on Structures ", by Professor J. D. Bernal, M.A., F.R.S.

(*b*) " The Design of Protective Structures and the Defence of Industry ", by Professor J. F. Baker, O.B.E., M.A., D.Sc., M. Inst. C.E.

(*c*) " A Survey of the Gas Contamination Problem in the Engineering Industry with Special Reference to Electrical Machinery ", by Major J. W. Martin, M.B.E., B.Sc.

16 December (Jointly with the Institution of Mechanical Engineers)—

" Hammer-Blow in Locomotives : can it not be abolished altogether ? " by Sir Harold N. Colam, B.A., M. Inst. C.E., and J. D. Watson, B.Sc., Assoc. M. Inst. C.E. ; and

" Balancing of Locomotive Reciprocating Parts," by E. S. Cox, A.M.I.Mech.E.

13 January (James Forrest Lecture)—
"Psychology as Applied to Engineering", by C. S. Myers, C.B.E., M.A., M.D., Sc.D., F.R.S.

10 February—
"Soil Mechanics and Site Exploration", by L. F. Cooling, M.Sc.; and
"Soil Mechanics in Road and Aerodrome Construction", by A. H. D. Markwick, M.Sc., Assoc. M. Inst. C.E.

10 March—
"The Surface Finishing of Concrete Structures," by Norman Davey, B.Sc., Ph.D., M. Inst. C.E.

14 April—
"Post-War Planning and Reconstruction," by H. J. B. Manzoni, C.B.E., M. Inst. C.E.

15 April (Jointly with the Institutions of Mechanical and Electrical Engineers)—
"The Application of Statistical Control to the Quality of Materials and Manufactured Products."
Subject introduced by Dr. C. G. Darwin, M.C., M.A., F.R.S., and Sir Frank Gill, K.C.M.G.

12 May—
"Treatment of Water for Domestic and Industrial Requirements: Some Problems and Methods", by Albert Parker, D.Sc.

Road Engineering Section.—This Section has held three meetings, all of which were well supported, a fact which is a happy augury for the success of the Section when its activities are more fully developed. A new Committee consisting of Sir Frederick C. Cook (Chairman), Mr. F. E. Wentworth-Sheilds, Mr. T. Peirson Frank, Dr. W. H. Glanville, Mr. W. E. Morgan, and Dr. R. E. Stradling, appointed by the Council, and Mr. H. E. Aldington, Mr. R. G. H. Clements, Mr. Arthur Floyd, and Mr. S. J. Higgs, elected by the members of the Section, came into office in September 1941. The following Papers have been discussed at meetings:—

30 September—
"Road Experiments on the Design of Thin Bituminous Surfacings", by Robert Slater, M.Sc., Assoc. M. Inst. C.E.

21 April—
"The Effects of Modern Road Layout on Bridge Design", by C. S. Chettoe, B.Sc. (Eng.), M. Inst. C.E.

2 June—
"Earthwork in Embankments", by R. M. Wynne-Edwards, D.S.O., M.C., M.A., M. Inst. C.E.

Railway Engineering Section.—This Section was formed in the summer of 1939, but, owing to the war, no meetings were held until 1942. The inaugural meeting took place early this year and was followed by a second

meeting in the spring. Judging by the demand for advance proofs of the Papers and by the numbers present at the meetings, the Council are well satisfied that the Section is of service to railway engineers. There is, indeed, no doubt whatever that the formation of Sections, as typified by the Railway and Road Engineering Sections, opens up opportunities of greater service to the profession, which will redound to the credit of The Institution and be to the advantage of the engineering profession.

The Committee consists of Mr. R. Carpmael (Chairman), Mr. W. T. Halcrow, Mr. A. S. Quartermaine, Mr. V. A. M. Robertson, and Mr. F. E. Wentworth-Sheilds, appointed by the Council, and Mr. George Ellson, Mr. C. E. Fairburn, Mr. J. C. L. Train, and Mr. W. K. Wallace, elected by the members of the Section. The following Papers have been presented and discussed :—

27 January—
"Permanent Way Tests and Practice on the L.M. & S. Railway", by W. K. Wallace, M. Inst. C.E.

28 April—
"The Repair of War Damage to Railway Way and Works in the London Area, 1940 and 1941", by Arthur Dean, M.Sc. (Eng.), Assoc. M. Inst. C.E.

Associations.—The Council are pleased to note that the Local Associations, in spite of war-time conditions, have been able to increase their activities during the past Session. The Edinburgh and Yorkshire Associations have, in fact, held their usual number of meetings and, with the exception of the Newcastle-upon-Tyne Association, the other Associations have all held several meetings. The number of joint meetings with local branches of kindred Institutions has shown a considerable increase.

A popular feature at Local Association meetings this Session has been the exhibition of a film illustrating the failure of the Tacoma Narrows Suspension Bridge, and of tests carried out on models in connexion therewith. This film was obtained from America through the courtesy of Professor F. B. Farquharson, of the Department of Civil Engineering, University of Washington, Seattle, who was responsible for the film.

No meetings of the Association of London Students have been possible, and the Council consequently decided that the Vernon-Harcourt Lecture for Students should not be given.

The work of the Malayan and Shanghai Associations has ceased owing to the war, but reports received since the last Annual General Meeting indicate that these Associations continued their activities during Session 1940–41, in conjunction with the Engineering Society of Malaya and the Engineering Society of China, respectively. The Malayan Association has awarded premiums to Mr. F. W. E. Tydeman, M. Inst. C.E., for his Paper on "The East Wharf Reconstruction," and to Mr. J. T. Chester,

Assoc. M. Inst. C.E., for his Paper on "Problems of Engineering Desig[n] and Construction met with in Malaya."

The Buenos Aires Association has had a number of successful meetings but no visits to works have taken place. Follett Holt premiums hav[e] been awarded as follows :—A senior premium to Mr. H. A. McGillycuddy B.E., M. Inst. C.E., for his Paper on "River Psychology and Some Adven-tures in River Training", and a junior premium to Mr. A. Hall, Stud. Inst. C.E., for his Paper on "Renewal of Track by Mechanical Means o[n] Single Line."

It is understood that the Jamaica branch of the West Indie[s] Association had a full programme of meetings for the current Session but no intimation has been received of the work of the Trinidad branc[h] of this Association.

Lectures to Students.—Reference was made in last year's Repor[t] to the negotiations which were proceeding for the establishment of [a] lectureship at Cambridge University in Engineering Economics, Manage-ment and Aesthetics. As then anticipated, it has not been possible i[n] war time to provide for the full adoption of proposals necessitating change[s] in the curriculum of engineering studies. A start has, however, bee[n] made and a series of lectures were delivered at Cambridge during th[e] Michaelmas and Lent terms. Several of these lectures were regarded as o[f] sufficient interest to engineers as a whole to be published in the Journa[l] of The Institution.

The Council have also acted on a suggestion that engineering student[s] at universities throughout the country should have an opportunity o[f] making contact with senior members of the profession through the mediu[m] of lectures dealing with the practical side of engineering, particularl[y] with the difficulties in the carrying-out, administration and managemen[t] of works of engineering construction. A panel of engineers willing t[o] give their services in this connexion has been prepared and a number o[f] Students' Engineering Societies have availed themselves of this opportunit[y] to meet practising engineers.

Recently the Institutions of Mechanical and Electrical Enginee[rs] have asked to be associated with the scheme, and to this the Council hav[e] most willingly agreed. In future the panel of lecturers will includ[e] prominent engineers from all three Societies.

Ingenuity Competition.—The entries for this competition, whic[h] closed on the 30th April 1941, numbered eighteen, and the Council divide[d] the prize of twenty-five guineas between :

L. B. Escritt, Assoc. M. Inst. C.E., for his Paper on "The Sanitatio[n] of Tube Railway Stations used for Air Raid Shelter" ; and

S. V. Gardner, Assoc. M. Inst. C.E., for his Paper on "Repair Wo[rk] to a Damaged Pumping-Station."

Both Papers were published in the December 1941 Number of th[e]

Journal, and about half-a-dozen of the remaining entries have also appeared in the Journal during the past Session.

In view of the encouraging response to this competition, the Council decided to hold a further competition, which resulted in fourteen entries being received by the 30th April last.

Post-War National Development.—Reference was made in last year's Report to the appointment of a Committee, under the Chairmanship of Sir Clement Hindley, to consider problems of post-war reconstruction, and this Committee has initiated a number of inquiries and investigations.

As the result of a conference between members of the Committee and representatives of the Ministry of Works and Buildings, at which it was stated that the Ministry would be glad to have an expression of the Committee's views on the proposals made in the Report of the Barlow Commission on the Distribution of the Industrial Population, and particularly on the form and functions of the proposed central planning authority, a report on this subject was prepared by a Sub-Committee, and submitted to the Minister of Works and Buildings, in July 1941. Since this report was prepared, information has been brought to the Committee's notice which necessitates some slight revision to the report, and the matter is at present under consideration by the Committee.

The question of delays in legislative procedure was the subject of consideration by another Sub-Committee, and a report, embodying recommendations for speeding up the procedure for the passage of Bills through Parliament, was placed before the Minister of Works and Buildings in September last.

A memorandum expressing the Committee's views on the subject of compensation and betterment has been submitted in response to a request from the Uthwatt Committee, and a memorandum on the location of industry in rural areas has been sent in reply to a request from Lord Justice Scott's Committee for evidence on this question.

The Sub-Committee appointed to make a general study of schemes and projects which could be put in hand after the war has continued its labours, and reports from panels dealing with various branches of engineering work are being examined. The reports on some classes of work are still outstanding, but it is hoped shortly to be able to present a comprehensive survey covering the main branches of engineering.

The subjects of post-war education, inland water survey, and colonial development are also under consideration by Sub-Committees of the Main Committee.

Co-operation.—The Council wish to place on record that the policy of close co-operation between the Institutions of Civil, Mechanical, and Electrical Engineers has been further strengthened during the past year, and that the Presidents of the three Societies have met on a number of occasions to consider problems of mutual interest with a view to effecting unity of purpose in their relations with Government departments and

others. In particular, the three Institutions are collaborating upon th matter of engineering education.

Armed Forces.—Co-operation with the War Office and with the Ai Ministry has continued, with a view to obtaining for members an Students opportunities for service in branches of the Armed Forces i which their technical qualifications may be utilized. Certificates o membership of The Institution have also been issued, as previously, fo the use of those applying for Commissions, or who are desirous of enterin the ranks of the Royal Engineers, and a special certificate has been availabl in the cases of young Students who wish to obtain reservation under th entry in the Schedule of Reserved Occupations relating to "studen engineering apprentices or learners", for the purpose of offering themselve for the first time for Sections A and B of the Associate Membershi Examination within two years of registration under the National Servic (Armed Forces) Acts. One hundred and ninety-three Students are now con tinuing their studies under the operation of the last-mentioned certificate

At the request of the Committee on Skilled Men in the Services (unde the Chairmanship of Sir William Beveridge), a deputation representing th Council of The Institution waited upon that Committee, and, as a result returns were obtained by means of a questionnaire from those member in the Armed Forces, giving details of their service. Reports based upo these returns have been made to the "Beveridge" Committee and to th War Office, which have resulted in a number of members being allocate to Units in which their technical qualifications are more fully utilized.

Up to the 31st March 1942, intimation of service with H.M. Arme Forces had been indicated by 2,615 Corporate Members and Students The Table on p. 343 shows their classification.

A number are serving with the Dominions Forces, particularly with th South African and New Zealand Forces.

Research.—The Committee which has been investigating the subjec of Fish Passes has completed its Report, and this is being publishe immediately. The Council wish to express their thanks to Dr. C. M. Whit for the careful and thorough laboratory investigation which he has made as shown in the Appendix to the Report, and which is of great value no only in connexion with the immediate subject dealt with, but also to al engineers interested in hydrodynamic problems.

Generally speaking, it has not been found possible, having regard t the difficulty of arranging meetings and the present concentration o problems relating to the war effort, to resume the work of the Researc Committee. Research is, however, being continued into the subject of th Soil Corrosion of Metals; the Department of Scientific and Industria Research is carrying out, on behalf of the Committee, a programme o research into the Thermal Expansion of Concrete; and the British Electrica and Allied Industries Research Association is completing certain test on a reduced scale into the Earthing of Waterpipes and Watermains.

	Members.	Associate members.	Associates.	Students.	Total.
Corps of Royal Engineers—					
Commissioned . . .	68	687	3	492	1,250
Non-Commissioned Officers and Other Ranks	—	39	—	452	491
Total .	68	726	3	944	1,741
In the Forces (other than Corps of Royal Engineers)—					
Commissioned—					
Royal Navy . . .	1	25	1	23	50
Army	13	122	2	129	266
Royal Air Force . .	5	58	1	71	135
Non-Commissioned Officers and Other Ranks—					
Royal Navy . . .	—	1	—	14	15
Army	1	16	—	211	228
Royal Air Force . .	—	10	—	61	71
Serving—branch not known	4	22	—	83	109
Total	24	254	4	592	874
Grand Total . .	92	980	7	1,536	2,615

Appointments.—The Council have made the following new appointments during the year :—

Mr. W. J. E. Binnie, M.A. — To the Association of Special Libraries and Information Bureaux, in place of the late Mr. C. G. Du Cane.

Mr. T. Peirson Frank — To the Engineering Joint Council, in place of Dr. D. Anderson (retired).

Mr. Frank Hibbert, M.C. — To the Court of the University of Liverpool, in place of Mr. Thomas Molyneux (retired).

Mr. J. R. Beard, M.Sc. — To the Executive Committee, British Standards Institution.

Mr. H. J. F. Gourley, M.Eng. — To the Engineering Divisional Council, British Standards Institution, in place of Sir Jonathan Davidson (retired).

Professor C. E. Inglis, O.B.E., M.A., LL.D., F.R.S.
Sir Clement D. M. Hindley, K.C.I.E., M.A. — To the Joint Co-ordinating Committee on Post-War National Development, Institutions of Mechanical and Electrical Engineers.

Sir Jonathan R. Davidson, C.M.G., M.Sc. Professor A. J. Sutton Pippard, M.B.E., D.Sc. The Secretary.	To the Engineering Sub-Committee o[f] the Executive Committee of the Anglo-Soviet Public Relations Association.

Accounts.—The Accounts for the year ending on the 31st March 194[2], which have been duly audited, are detailed in the Appendix to this Repor[t] (pp. 352–362, *post*), and may be summarized briefly as follows :—

The *Total Income* for the year amounted to . . . . . £42,93[3]
(as compared with £44,164 last year) including £538 for Income Tax recovered. Subscriptions, Entrance fees, and Examination fees totalled £41,150 (as compared with £42,564 last year), and Dividends and Interest received amounted to £1,119 (as compared with £1,148 last year).

The *Total Expenditure* charged against the year's Income amounted to . . . . £41,69[5]
(as compared with £41,790 last year) including Provisions of £12,000 (viz. £11,000 for Publications Account and £1,000 for Research Reserve).

The *General Revenue Account* therefore results in a credit balance of . . . . £1,23[8]
to which has been added the credit balance of £2,249 brought forward from last year, resulting in a final credit balance of £3,487.

Cash at bankers and in hand amounted to £20,806 (compared wit[h] £17,567 last year) at the close of the financial year, due to the receipt, a[s] in past years, of a substantial proportion of the current subscriptio[ns] during the first quarter. This balance is required to finance expenditu[re] during the remainder of the year.

The actual expenditure during the year on " Publications Account " amounted to £11,812 (compared with £10,156 last year), of which £8,2[5.] represented the cost of the Journal. This expenditure was relieved b[y] credits for advertisements, sales, etc., of £2,647 (against £2,823 last yea[r]) leaving the net expenditure for the year at £9,165 (compared with £7,33[3]). This amount was £1,835 less than the £11,000 allocated, and the cred[it] balance carried forward is £624.

The Research Reserve credit balance has increased by £786 during t[he] year, viz. from £3,451 to £4,237. The expenditure incurred amounted [to] £1,264, whereas the credits (made up of the appropriation from Reven[ue] Account of £1,000, and contributions by outside bodies of £1,050) totall[ed] £2,050.

The Repairs and Renewals Reserve credit balance has been increas[ed] by £1,828 during the year, viz. from £8,252 to £10,080.

On Trust Funds Income Account there was received a total of £1,273, and the expenditure amounted to £554.

During the year sums of £15 in interest and £10 from sales of reports have been credited to the research into the Deterioration of Structures exposed to Sea-Action.

Examinations.—The number of candidates who applied through The Institution and attended the Common Preliminary Examination conducted by the Engineering Joint Examination Board was 53 for the October 1941 Examination, and 94 for the April 1942 Examination.

The number of candidates examined in the October 1941 Associate Membership Examination in whole or in part was 289, an increase of 58 on last year's figure, including 64 at 19 centres overseas. For the April 1942 Examination there were 318 candidates, as compared with 296 last year at home, and 45 overseas at 13 centres.

Bayliss Prizes of the value of £15 have been awarded to Mr. Jack Beetham of Burnley, an approved candidate for election, in respect of Sections A and B of the Associate Membership Examination for April 1941, and Mr. George Alexander Flook, Stud. Inst. C.E., in respect of the October 1941 Examination.

The Council have extended until the end of the year 1943 the transitional period during which the qualifications at present accepted under their rules as exempting from the Institution Preliminary Examination will continue to be recognized as fulfilling the requirements in respect of general education for the purpose of entry into The Institution, in addition to the qualifications accepted by the Joint Board as exempting from the Common Preliminary Examination.

The Council have decided that Section B of the Associate Membership Examination should be more comprehensive in character so as to cover more fully the various branches of engineering, and the syllabuses are being revised accordingly. This section will now consist of, in addition to the compulsory subject "Engineering Drawing", sixteen subjects in nine groups, instead of ten subjects in three groups, as heretofore. The date of the first examination under the revised syllabus will be announced later.

The arrangement referred to in last year's Report regarding vocational courses of study by correspondence for men serving in H.M. Forces, arranged between the War Office and the Institutions of Civil, Mechanical, and Electrical Engineers, is now in operation, and a number of men are known to be taking advantage of the scheme, which, as far as The Institution is concerned, covers subjects in both Sections A and B of the Associate Membership Examination. Owing to the limited time available for study in the cases of many men in the Services, the Council have agreed to permit them to sit for two subjects only at a time.

Arrangements have also been made through the British Red Cross Society to extend the scheme to prisoners of war in camps in Germany.

A number of such prisoners have taken up the course and already eighteen have expressed the wish to attend the examination in October next. It is hoped that, with the assistance of the British Red Cross Society, it will be possible to arrange for the examination to be held at the camps, the actual superintendence of the candidates being undertaken by the camp leaders.

Scholarships.—The Palmer Scholarship of £45 per annum for 3 years awarded in 1938 to Paul Graham Mann, of Southport, to assist him to pursue a degree course of medical study at the University of Cambridge, has been extended for a further year. A Palmer Scholarship of £30 per annum for 2 years has also been awarded to Gerald Pilkington Ward, of Bournemouth, to assist him to complete a course of study leading to the B.A. Honours Mechanical Sciences Tripos of the University of Cambridge.

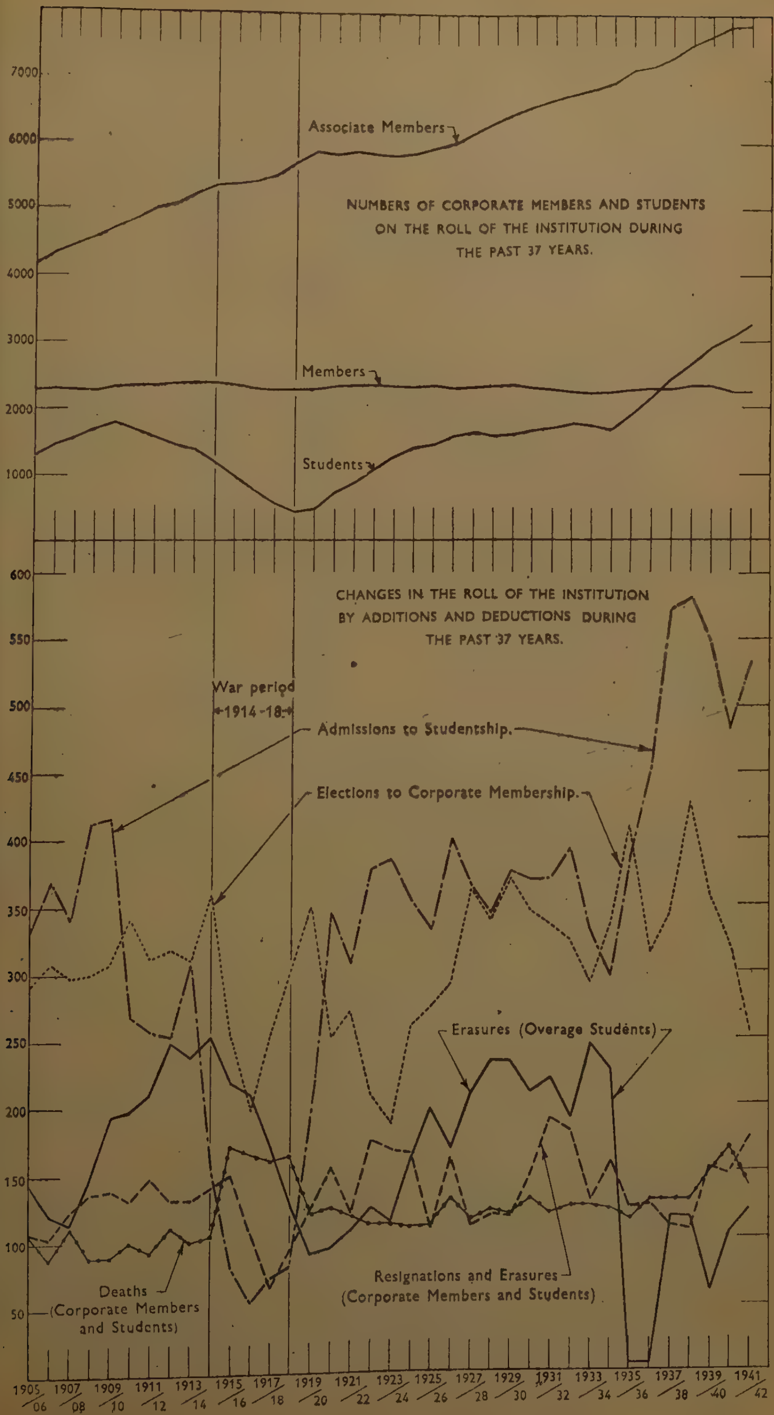
On a recommendation from the Glasgow and District Association of The Institution, a C. C. Lindsay Scholarship of £30 per annum for 2 years has been awarded to Maurice Aiton, of Glasgow, to assist him to pursue a course of study in the subjects of the Associate Membership Examination at the Royal Technical College, Glasgow, or other approved college.

James Alfred Ewing Medal.—On the joint nomination of Professor C. E. Inglis, President of The Institution, and the late Sir William Bragg, Acting President of the Royal Society, the Council have awarded the James Alfred Ewing Medal for 1941 to Dr. Frederick William Lanchester, F.R.S. The medal is awarded for specially meritorious contributions in the field of research.

Library.—During the year, 434 volumes were presented to the Library, and 378 were purchased, making a total, on the 31st March 1942, of 64,582. 1795 applications for the loan of books were dealt with, this total being 564 more than in Session 1940–41. An increasing number of inquiries has been received from the Services and Government departments.

Gifts.—Sir Clement Hindley, President 1939–40, and Sir Leopold Savile, President 1940–41, have presented to The Institution their portraits, painted by Anthony Devas and Ernest Jackson respectively; and a portrait of Lt.-Colonel John Pitt Kennedy, former M. Inst. C.E., one of the founders of the Bombay, Baroda and Central India Railway Company, has been presented by that Company. Other gifts received by The Institution during the year include a bronze plaque in bas-relief of the late Sir Robert A. Hadfield, presented by Messrs. Hadfield, Ltd., and an illustrated volume describing the Victoria Bridge, Canada, presented by Lady Willingdon, grand-daughter of the contractor to the bridge, the late Thomas Brassey.

The Roll.—The present time may be opportune for the publication of the accompanying graph showing the number of corporate members and students on the roll of The Institution during the past 37 years, as well as the annual changes by additions and deductions during the same period



7000
6000
5000
4000
3000
2000
1000
Associate Members
NUMBERS OF CORPORATE MEMBERS AND STUDENTS ON THE ROLL OF THE INSTITUTION DURING THE PAST 37 YEARS.
Members
Students
600
550
500
450
400
350
300
250
200
150
100
50
CHANGES IN THE ROLL OF THE INSTITUTION BY ADDITIONS AND DEDUCTIONS DURING THE PAST 37 YEARS.
War period 1914-18
Admissions to Studentship.
Elections to Corporate Membership.
Erasures (Overage Students)
Resignations and Erasures (Corporate Members and Students)
Deaths (Corporate Members and Students)
1905/06
1907/08
1909/10
1911/12
1913/14
1915/16
1917/18
1919/20
1921/22
1923/24
1925/26
1927/28
1929/30
1931/32
1933/34
1935/36
1937/38
1939/40
1941/42

During the year ending on the 31st March 1942, 1 Honorary Member, 9 Members, 244 Associate Members, and 2 Associates were elected, 533 candidates were admitted as Students, and the names of 1 Member, 12 Associate Members, and 5 Students were restored to the Roll. From this addition of 807 must be deducted the deaths, resignations, erasures, over-age Students, and the Students elected Associate Members, amounting to 578 in all, showing a net increase of 229; 54 Associate Members were transferred to the class of full Members. The Roll on the 31st March 1942, stood at 13,427, the changes which took place during the year ending on that date being shown in the following Table :—

	1 April 1940, to 31 March 1941.						1 April 1941, to 31 March 1942.					
	Honorary members.	Members.	Associate members.	Associates.	Students.	Totals.	Honorary members.	Members.	Associate members.	Associates.	Students.	Totals.
Numbers at commencement	19	2303	7680	51	2906	12,959	16	2237	7819	49	3077	13,198
Transfers—Associate Members to Members	..	+34	−34	..	..		..	+54	−54	..	..	
Elections	1	5	313	..	..		1	9	244	2	..	
Admissions	..	..	..	..	482	+818	..	..	..	..	533	+807
Restored to Roll	..	..	13	..	4		..	1	12	..	5	
Deceased	2	80	71	1	16		3	54	57	4	29	
Resigned	..	22	49	1	8		..	11	47	..	16	
Erased	2	3	31	..	35		..	6	48	1	45	
Elected as Associate Members	..	..	..	..	148	−579	..	..	..	..	126	−578
Removed over-age	..	..	..	..	104		..	..	..	..	120	
Failed to complete	..	..	2	..	4		..	..	6	..	5	
						+239						+229
Numbers at termination	16	2237	7819	49	3077	13,198	14	2230	7863	46	3274	13,427

Deaths.—It is with especial regret that the Council have to record the deaths of H.R.H. the Duke of Connaught and Strathearn, K.G., of Sir William H. Bragg, O.M., K.B.E., and Sir Robert Elliott-Cooper, K.C.B. (Past-President), Honorary Members; of Mr. C. L. Howard Humphreys, O.B.E., T.D., Member of Council; of the Rt. Hon. Lord Cadman of Silverdale, G.C.M.G., D.Sc., and Maurice Deacon, former Members of

Council; of 27 Members and Students on active service, and of 5 Members and Students as a result of enemy action.

The full list of deaths is as follows (*E.* refers to election, *T.* to transfer, and *A.* to admission):—

DEATHS.—*Honorary Members* (3).—*H.R.H.* Arthur, Duke of Connaught and Strathearn, K.G., P.C., G.B.E. (E. 1872); *Sir* William Henry Bragg, O.M., K.B.E., M.A., D.Sc., Sc.D., LL.D., D.C.L., F.R.S. (E. 1936); *Sir* Robert Elliott-Cooper, K.C.B. (E. 1870. T. 1876. E. *Hon. Member*, 1938).

Members (54).—John Ball, O.B.E., Ph.D., D.Sc. (E. 1899. T. 1911); Cecil William Edwin Bishop, B.Sc. (E. 1926. T. 1939); Harry Blundell (E. 1886. T. 1899); William Brodie (E. 1899. T. 1914); Robert Harold Brookhouse (E. 1883. T. 1889); Edward Otto Forster Brown (E. 1924); Joseph William Buckley (E. 1895. T. 1911); George William Buckwell (E. 1906); *The Rt. Hon. Lord* Cadman of Silverdale, G.C.M.G., D.Sc. (E. 1911) (*former Member of Council*); John Haydon Cardew (E. 1890. T. 1908); Joseph Cash (E. 1872. T. 1891); Cecil Bourke Connell (E. 1912. T. 1930); Ernest Walter Cook (E. 1905. T. 1937); Alfred Chorley Cookson (E. 1895. T. 1907); Charles Frederick Courtney (E. 1894); John Campbell Coutts, B.Sc. (E. 1919. T. 1938); Edward Woodrowe Cowan (E. 1887. T. 1904); Thomas Davies, O.B.E. (E. 1920); Maurice Deacon (E. 1886. T. 1892) (*former Member of Council*); Thomas Clark Deverell (E. 1886. T. 1900); Cecil Burton Ede (E. 1912. T. 1926); Frank Dudley Evans, C.B.E. (E. 1908. T. 1927); Joseph Fearfield, C.I.E., B.A. (E. 1909. T. 1928); Hugo Robert Ford (E. 1889. T. 1906); Robert Halley Garvie, B.Sc. (E. 1902. T. 1916); *Sir* Herbert Nigel Gresley, C.B.E. (E. 1914); André Pierre Griffiths, B.Sc. (E. 1893. T. 1905); John Henry Hanson (E. 1881. T. 1914); Edgar Purnell Hooley (E. 1886. T. 1906); Cecil Lee Howard Humphreys, O.B.E., T.D. (E. 1921. T. 1929) (*Member of Council*); John Theodore Hunt, B.A., B.A.I. (E. 1905. T. 1912); Philip Charles Holmes Hunt (E. 1911); William Hutchinson, M.C.E. (E. 1886. T. 1891); Henry Jones (E. 1910); James Howie Kirkwood, B.Sc. (E. 1897. T. 1927); John Douglas Knight (E. 1908. T. 1920); Gordon Colet Laurie (E. 1901. T. 1909); Henry Dacre Madden (E. 1923); Robert Mair, M.C., B.Sc. (E. 1917. T. 1933); Walter Leahy Mansergh (E. 1897. T. 1908); Thomas Lodwick Miller, O.B.E. (E. 1885. T. 1899); Charles Hamilton Mitchell, C.B., C.M.G., D.S.O., B.A.Sc. (E. 1906. T. 1912); Julian Money Vernon Money-Kent (E. 1898. T. 1914); Hugh Hamilton Newell, C.B.E. (E. 1929); William Frank Pettigrew (E. 1884. T. 1894); Lionel Godfrey Redmond (E. 1921); Alan Wood Rendell, V.D. (E. 1888); Henry Robinson (E. 1913. T. 1922); Christer Peter Sandberg, C.B.E. (E. 1902. T. 1918); Lancelot Horace Augustus Shadwell, O.B.E., R.N.V.R. (*ret.*) (E. 1904. T. 1922); Gilbert Thomson, M.A. (E. 1901. T. 1911); Frank Eardley Turner (E. 1928. T. 1937); John Russell Warren, M.C., B.Sc. (E. 1915. T. 1925); Albert Wilson, B.Sc. (E. 1904. T. 1928).

Associate Members (57).—Frank Eardley Apted (E. 1906); Robert Douglas Archibald, B.Sc. (E. 1907); Lawrence Joseph Ball (E. 1939); Leslie Holding Barnes (E. 1914); Raymond John Birt (E. 1890); Walter Norman Bolam, B.Sc. (E. 1905); Frederick William Bowden (E. 1893); Fergus Brown (E. 1925); Julian Edward Caccia (E. 1892); Frederick William Carne (E. 1891); Frederic Edward Theodore Cobb (E. 1885); Eric Hatch Coles, B.Eng. (E. 1939); Herbert Martin Coombs, B.Sc. (E. 1938); Frederick Southwell Cripps (E. 1888); Gokul Kilabhai Dalal (E. 1915); Arthur Joseph Daly, B.E. (E. 1920); George Herbert Wrigley Dawson, M.A. (E. 1905); Arthur Dodgeon (E. 1908); Sydney Charles Early (E. 1887); Osborne Anthony George Edwards (E. 1886); Eduardo de Moraes Gomes Ferreira (E. 1884); Charlie Flowers, B.Sc. (E. 1916); David Benny Frew, M.C., B.Sc. (E. 1913); Alfred Reginald Goldthorp, B.Sc. (E. 1923); Ivor Ellis Gooch (E. 1929); William John Alexander Gray (E. 1935) Albert Edward Greig (E. 1931); John Jackson Hamilton, B.A. (E. 1940); William Edwin Hayward (E. 1937); Christopher Basil Hume Henderson, B.Sc. (E. 1935); William Hogg, B.A.I. (E. 1908); Francis Eliot Howard (E. 1901); Charles James Jackaman (E. 1885); Ronald Mackenzie Lawrence (E. 1920); Francis Thomas Lee-Norman, M.C., B.A. (E. 1913); Gustave Michael de Lembcke, M.A. (E. 1921); Harold Edward Lockhart (E. 1886); William Wright Marriner, B.Sc. (E. 1894); Charles

Murray (*E.* 1890); John Switzer Owens, M.D. (*E.* 1902); Thomas Wint Weir Parker (*E.* 1910); Hartley Blyth Pratt (*E.* 1921); John Rosslyn Rhedynog Price, B.Sc. (*E.* 1937); Ralph Baron Rogers, M.A. (*E.* 1888); John Bedford Rowe (*E.* 1905); Graham Wilfred Sainsbury, M.C., B.Sc. (*E.* 1920); William Savage (*E.* 1895); Ernest Kilburn Scott (*E.* 1899); Percival Frederic Dreweatt Seale, B.Sc. (*E.* 1939); John George Shakespeare (*E.* 1929); Samuel Percy Squire (*E.* 1932); Martin Richard Furnneaux Henessy Stuart (*E.* 1922); Farquhar Tait (*E.* 1913); David Gibb Tippett, B.Sc. (*E.* 1933); John Triffitt (*E.* 1894); Theodore Charles Troubridge Walrond (*E.* 1883); Cecil Wrenne Williams, B.A. (*E.* 1902).

Associates (4).—George Balfour, M.P. (*E.* 1931); Lachlan Paterson Mackenzie (*E.* 1910); *Sir* Edmund Keith Nuttall, *Bart.* (*E.* 1932); Gilbert Richard Redgrave (*E.* 1872).

Students (29).—Alfred Arnold Alsop (*A.* 1939); Francis Michael Armstrong (*A.* 1941); John Woodrow Arnott (*A.* 1936); Howard Ivor Barnard (*A.* 1937); John Eglington Bate (*A.* 1934); Leonard Richard Blackwell, B.Sc. (*A.* 1935); Robert Brockbank (*A.* 1937); Charles Cyril Byrom (*A.* 1938); Donald McKenzie Chapman (*A.* 1939); William Joseph Coats (*A.* 1937); Donald Alastair Coode (*A.* 1938); Norman William Dent (*A.* 1939); Alban Gladstone Griffith, B.A. (*A.* 1937); John Ross Monro Hector, B.E. (*A.* 1937); Merrik Hubert Eric Hine (*A.* 1937); Philip Norman Horner (*A.* 1938); John Denys Marsh Lyons, B.A. (*A.* 1936); John Mayo (*A.* 1941); Richard George Medd (*A.* 1937); James Spence Nairn (*A.* 1937); Hyam Solomon Reuben (*A.* 1938); Robert Edward Rogers (*A.* 1940); John Joscelyne Sayer, B.Sc. (*A.* 1936); Francis Eric Sheals (*A.* 1936); Fred Hugh Sykes (*A.* 1939); William David Vaughan (*A.* 1933); Peter Timothy Vowles (*A* 1935); Frank Thomas Bernard Wadsworth (*A.* 1938); Ronald Stuart Wells (*A.* 1938).

The following resignations have been received :—

Members (11).—James Maclean Alexander (*E.* 1912); Charles Benjamin Collett, O.B.E. (*E.* 1922); Norman Bonnington Dickson (*E.* 1895. *T.* 1901); Ernest Cranston Given (*E.* 1896. *T.* 1906); Clements Frederick Vivian Jackson, B.E. (*E.* 1899. *T.* 1920); James Foster King, C.B.E. (*E.* 1910); William Longbottom (*E.* 1912. *T.* 1924); Thomas Leigh Matthews (*E.* 1905. *T.* 1913); Leonard Leslie Robinson (*E.* 1906. *T.* 1912); Gordon William Thom, M.C.E. (*E.* 1911. *T.* 1918); James Henry Thurstan (*E.* 1919).

Associate Members (47).—Frederick Guy Trevenen Adams (*E.* 1906); Samuel Henry Adams (*E.* 1900); Habib Basta (*E.* 1907); Benjamin Donald Hewitt Bean (*E.* 1913); Geoffrey James le Breton Beaumont (*E.* 1931); Othman Frank Blakey, M.E. (*E.* 1936); Hector Elie de Boissière, B.Sc. (*E.* 1899); James Lord Bowness (*E.* 1906); James Brierley, O.B.E. (*E.* 1908); William Rochester Brown (*E.* 1913); Geoffrey Armstrong Buddle, D.S.O., M.C., B.Sc. (*E.* 1919); Lawrence Statter Carr (*E.* 1894); George Leonard Cassidy (*E.* 1929); William Young Chamberlain (*E.* 1899); John Henry Chaloner Chute (*E.* 1893); Albert Hawkins Clark (*E.* 1905); *Col.* Harold Eustace Coad, R.E. (*E.* 1907); Walter Robinson Crabtree, M.Sc. (*E.* 1895); Howard Maurice Edmunds, M.C. (*E.* 1910); Lindsay Ernest Edwards (*E.* 1920); Arthur Nelson Forman, B.Sc. (*E.* 1920); John Hastings Glendinning, B.Sc. (*E.* 1926); Alfred Guest, B.Eng. (*E.* 1910); Harold Wilfrid Hague (*E.* 1916); Harold Cunliffe Hilton (*E.* 1905); Andrew Martin Ker, B.Sc. (*E.* 1902); Malcolm Glen Kidston, B.Sc. (*E.* 1910); James Gunson Lawn, C.B.E. (*E.* 1896); John William Liversedge (*E.* 1907); Frederick Percy Manson (*E.* 1907); Matthew Mawson (*E.* 1894); Geoffrey Horace Mutimer (*E.* 1932); Gerald Leighton Nanson, B.E. (*E.* 1935); Henry Algernon Frazer Nash (*E.* 1920); William Lowell Francis Palmer (*E.* 1906); Guy Addison Phillips (*E.* 1933); Arthur Rogers (*E.* 1905); James Shaw Rogers (*E.* 1904); Basil James Searle (*E.* 1903); Robert Melville Smith (*E.* 1908); Hedley Jeffreys Thomson (*E.* 1912); Patrick Tohall, B.E. (*E.* 1922); Charles Harold Waithman (*E.* 1909); George Dutton Walker (*E.* 1904); Eric Bell Walton (*E.* 1922); Stafford Tracey Watts (*E.* 1908); Alfred John Weale (*E.* 1929).

Students (16).—Edwin Alexander Andrews (*A.* 1937); William George Bruce (*A.* 1932); Ronald Maurice Canning (*A.* 1938); Konrad Joachim Friedlaender (*A.* 1938); Douglas Fyall, B.Sc. (*A.* 1937); Ian Rendell Hedger (*A.* 1939); Aeneas

Alexander Henderson (*A*. 1939); James Edgar Holme (*A*. 1936); Norman Ragnar Logsdon (*A*. 1938); John Falconer McFarlane (*A*. 1939); William Millar (*A*. 1932); Anthony John Peach (*A*. 1940); Frank William Peach (*A*. 1932); Alexander Henderson Rutherford (*A*. 1939); John Thompson Shepherd (*A*. 1939); Sudhir Kumar Sinha (*A*. 1939).

BALANCE SHEET

	£	s.	d.	£	s.	d.
INSTITUTION CAPITAL ACCOUNT AND BUILDING FUND						
As per last Account	..			416,323	16	1
RESERVES						
Repairs and Renewals, *as detailed on pages 354 and 355*	10,080	3	0			
Publications, *as detailed on pages 354 and 355* .	624	10	10			
Research, *as detailed on pages 360 and 361* . .	4,237	5	4			
				14,941	19	2
GENERAL REVENUE ACCOUNT SURPLUS						
Balance at 31st March, 1941	2,249	9	11			
Surplus for the year to date, per account *page 356*	1,237	15	9			
				3,487	5	8
				434,753	0	11
CREDITORS	..			7,059	15	11
REVENUE IN SUSPENSE						
Proportion of subscriptions and examination fees received relating to the period after 31 March, 1942				19,688	12	1
				461,501	8	11
TRUST FUNDS—						
Capital Accounts (*see pages 358 and 359*) . . .	38,232	12	5			
Unexpended Income (*see pages 360 and 361*) .	4,284	12	8			
				42,517	5	1
SEA ACTION COMMITTEE ACCOUNT—						
As detailed on pages 360 and 361	..			1,060	17	7
				£505,079	11	7

AUDI

We have audited the above Balance Sheet dated 31st March, 1942, and have ob
is properly drawn up so as to exhibit a true and correct view of the state of The Instit
shown by the books of The Institution.

London, 4th May, 1942.

DIX

31st MARCH, 1942.

	£ s. d.	£ s. d.	£ s. d.
FREEHOLD PROPERTY—Institution Building—			
At cost, as per last Account		..	375,767 16 10
INSTITUTION INVESTMENTS (including those held in respect of Repairs and Renewals Reserve) at or under cost, *as detailed on page 362*		..	63,294 0 4
Note.—*Market value at 31st March, 1942* £62,364			
DEBTORS		..	1,633 8 5
CASH AT BANKERS AND IN HAND .		..	20,806 3 4
			461,501 8 11
TRUST FUND ASSETS—			
Capital:—			
Investments, *as detailed on pages 358 and 359* . . .	38,230 10 5		
Cash at Bankers	2 2 0		
		38,232 12 5	
Unexpended Income:—			
Investments, *as detailed on page 359*	214 8 2		
Cash at Bankers and on Deposit Account . . .	4,070 4 6		
		4,284 12 8	
			42,517 5 1
SEA ACTION COMMITTEE ACCOUNT—			
£1,000 3% Savings Bonds 1955/65 at cost . .		1,000 0 0	
Cash at Bankers		60 17 7	
			1,060 17 7
			£505,079 11 7

E. Graham Clark, *Secretary.*

ORT.

e information and explanations we have required. In our opinion such Balance Sheet
s according to the best of our information and the explanations given to us, and as

Alan Rae Smith
J. D. C. Couper } Auditors.

RESERVE FOR REPAIRS AND RENEWALS TO

	£	s.	d.
To Net Expenditure during the Year	401	7	
„ Balance *carried down*	10,080	3	
	£10,481	10	

PUBLICATION

	£	s.	d.	£	s.	d.
To Balance, *per last account*				1,210	3	
„ Expenditure during the Year—						
Journal	8,259	6	10			
Charters, By-laws and Lists of Members	461	5	3			
Engineering Abstracts	16	17	6			
Salaries and Pension Premiums	2,978	4	7			
Sundries, including reporting	96	14	7			
	11,812	8	9			
Less Credits for Advertisements, Sales, Contributions, etc	2,647	3	6			
				9,165	5	
„ Balance *carried down*				624	10	
				£11,000	0	

STRUCTURE, FURNITURE, FITTINGS AND MACHINERY.

	£	s.	d.
By Balance, *per last account*	8,252	12	4
,, Institution Revenue Account—Amount provided for the year—*per page 356*	2,000	0	0
,, Interest on Investments	202	6	2
,, Income Tax Refunded	26	12	2
	£10,481	10	8
By Balance *brought down*	10,080	3	0
	£10,080	3	0

REVENUE ACCOUNT.

	£	s.	d.
By Institution Revenue Account—Amount provided for the year—*per page 356*	11,000	0	0
	£11,000	0	0
,, Balance *brought down, as per Balance Sheet (page 352)*	624	10	10

1940–41	EXPENDITURE.				
£		£	s.	d.	£
	To HOUSE AND ESTABLISHMENT CHARGES—				
	Rates, Health, Unemployment and other Insurances	4,875	17	7	
	Electric Lighting and Power, Water Supply, Warming, Ventilating, and Telephone	1,093	10	5	
	Cleaning and Household Expenses	1,825	6	10	
	Refreshments and Assistance at Meetings . . .	57	9	10	
8,472					7,852
	,, REPAIRS AND RENEWALS RESERVE—				
1,000	Amount provided for the year, *per page 355* . .	..			2,000
1,600	CONTRIBUTIONS PAYABLE UNDER THE WAR DAMAGE ACT, 1941 (including provision for period 1st September, 1941, to 31st March, 1942)	..			1,421
	,, SALARIES, WAGES AND RETIRING ALLOWANCE—				
	Salaries	2,094	19	2	
	Retiring Allowance	355	0	0	
	Clerks and Messengers	5,272	17	10	
	Premiums on Staff Pension Policies	1,373	13	2	
9,144					9,096
	,, STATIONERY, POSTAGES, ETC.—				
	Stationery and Printing	856	5	1	
	Postages, Telegrams and Parcels	858	5	8	
1,591					1,714
12,000	,, PUBLICATIONS REVENUE ACCOUNT—				
	Amount provided for the year, *per page 355* . .	..			11,000
	,, RESEARCH RESERVE—				
1,300	Amount provided for the year, *per page 361* . .	..			1,000
	,, CAMBRIDGE LECTURESHIP	..			1,000
	,, LIBRARY—				
	Books and Periodicals	439	13	6	
	Binding	181	18	11	
	Salaries and Pension Premiums	1,044	3	2	
1,722					1,665
	,, EXAMINATION EXPENSES—				
	Examiners, Printing and General	1,313	8	7	
	Salaries and Pension Premiums	1,986	4	0	
	Postages	118	7	2	
3,392					3,417
71	,, ANNUAL LUNCHEON	..			45
82	,, DIPLOMAS	..			36
	,, LOCAL ASSOCIATIONS—				
927	Grants to Local Associations, etc.	..			595
75	,, CONTRIBUTIONS TOWARDS ADVISORY COMMITTEES IN THE DOMINIONS	..			105
	,, GRANTS AND CONTRIBUTIONS—				
	British Standards Institution	50	0	0	
	Engineering Joint Council	12	10	0	
	Westminster Hospital	10	10	0	
	World Power Conference	3	18	9	
81					76
	,, LEGAL AND OTHER PROFESSIONAL CHARGES—				
	Legal Charges	24	1	3	
	Audit Fee	183	15	0	
	Engineers' Charges	5	5	0	
	Surveyors' charges	69	10	6	
323					282
10	,, TRAVELLING EXPENSES TO COMMITTEES	..			63
	,, POST WAR NATIONAL DEVELOPMENT COMMITTEE .	..			321
£41,790					41,695
2,374	,, BALANCE, BEING EXCESS OF INCOME OVER EXPENDITURE FOR THE YEAR AS PER BALANCE SHEET, page 352	..			1,237
£44,164					£42,933

OM 1st APRIL, 1941, TO 31st MARCH, 1942.

INCOME.

	£ s. d.	£ s. d.	1940–41 £
Subscriptions received applicable to the Financial Year 1941–1942	..	36,252 19 8	*35,939*
Entrance Fees	..	3,870 6 0	*4,337*
Life Composition	..	100 0 0	—
Interest, Dividends, etc.—			
On Institution Investments	1,059 0 0		
On Current Account etc.	60 3 7		
Income Tax refunded for the year 1940–41	538 5 7	1,657 9 2	*1,580*
Examination Fees for the October, 1941, and April, 1942, Examinations	2,753 10 0	..	—
Less Fees for April, 1942, examination carried forward	1,725 10 0	1,028 0 0	*2,288*
Library Fund Donations	..	24 13 8	*20*
		£42,933 8 6	*£44,164*

CAPITAL ACCOUNTS AND INVESTMENT THEREOF AND INVESTMEN

Capital Accounts.		Investments. Capital.	Unexpended Income.
£ s. d.		£ s. d.	£ s. d.
8,038 9 4	TELFORD FUND.		
	£8,738 13s. 0d. 2½% Consols . .	7,988 9 4	
	£50 16s. 11d. 3½% War Loan . .	50 0 0	
270 0 0	MANBY DONATION.		
	£250 London & North-Eastern Railway 4% 2nd Guaranteed Stock	270 0 0	
6,337 12 4	MILLER FUND.		
	£5,129 17s. 5d. 2½% Consols . .	4,850 2 4	
	£1,513 15s. 9d. 3½% War Loan. .	1,487 10 0	
500 0 0	HOWARD BEQUEST.		
	£352 11s. 5d. 2½% Consols . . Cost of Medal Die	500 0 0	
600 0 0	TREVITHICK MEMORIAL.		
	£103 2½% Consols	100 0 0	
	£506 5s. 7d. 3½% Conversion Loan 1961	500 0 0	
540 0 0	CRAMPTON BEQUEST.		
	£512 15s. 11d. 2½% Consols. . .	500 0 0	
	£40 13s. 7d. 3½% War Loan . .	40 0 0	
1,234 14 0	JAMES FORREST LECTURE AND MEDAL FUND.		
	£465 Southern Railway 4% Debenture Stock	604 14 0	
	£667 5s. 8d. 3½% War Loan . .	630 0 0	
1,647 10 10	PALMER SCHOLARSHIP.		
	£1,650 10s. 0d. 3% Redemption Stock, 1986–1996	1,547 10 10	
	£100 9s. 8d. 3½% War Loan . .	100 0 0	
1,080 0 0	JOHN BAYLISS BEQUEST.		
	£1,013 17s. 10d. London County 3% Stock, 1920	1,000 0 0	
	£80 7s. 10d. 3½% War Loan . .	80 0 0	
1,318 11 8	THE INDIAN FUND.		
	£1,353 4s. 2d. 2½% Consols . .	1,148 11 8	
	£171 13s. 3d. 3½% War Loan . .	170 0 0	
1,000 0 0	VERNON-HARCOURT BEQUEST.		
	£1,082 9s. 10d. London County 3% Stock, 1920	1,000 0 0	
22,566 18 2	*Carried forward*	22,566 18 2	

FUNDS.

OF UNEXPENDED INCOME AT 31ST MARCH, 1942.

Capital Accounts £	s.	d.		Investments: Capital £	s.	d.	Investments: Unexpended Income £	s.	d.
22,566	18	2	*Brought forward*	22,566	18	2			
1,300	0	0	WEBB BEQUEST.						
			£1,055 7s. 2d. Metropolitan Water Board 3% "B" Stock	1,000	0	0			
			£303 16s. 2d. 3½% War Loan	300	0	0			
2,948	8	0	WILLIAM LINDLEY FUND.						
			£1,214 London Midland & Scottish Railway 4% Debenture Stock	1,584	16	8			
			£1,221 1s. 4d. 3% Savings Bonds 1955/65	1,221	1	4			
			£151 9s. 7d. 3½% War Loan	142	10	0			
725	0	0	KELVIN MEDAL FUND.						
			£757 18s. 11d. 3½% War Loan	725	0	0			
4,250	0	0	CHARLES HAWKSLEY BEQUEST.						
			£955 Metropolitan Water Board 3% "B" Stock	573	0	0			
			£500 South Essex Waterworks 5% Preference Stock	435	0	0			
			£70 5% Sheffield Corporation Water Annuities; £40 4% Sheffield Corporation Water Annuities	1,992	0	0			
			£1,257 17s. 4d. 3½% War Loan	1,250	0	0			
1,101	6	5	COOPERS HILL WAR MEMORIAL.						
			£1,239 15s. 0d. 3½% War Loan	1,101	6	5			
			£215 12s. 3d. 3½% War Loan	..			214	8	2
3,570	4	0	C. C. LINDSAY CIVIL ENGINEERING SCHOLARSHIP FUND.						
			£3,500 3½% War Loan	3,570	4	0			
320	0	0	BAKER MEDAL FUND.						
			£290 5s. 8d. London County Cons. 4½% Stock, 1945–85	320	0	0			
809	11	0	JAMES ALFRED EWING MEDAL FUND.						
			£798 12s. 9d. Middlesex County Council 3% Stock, 1961–1966	807	9	0			
641	4	10	G. H. DENNISON FUND.						
			£706 3s. 2d. 3% Local Loans	641	4	10			
38,232	12	5	*As per Balance Sheet, page 353*	38,230	10	5	*214	8	2

NOTE.—**The Value of these Investments at ruling prices on 31st March, 1942, amounted approximately to £38,762 and £228 respectively.*

TRUST FUNDS INCOME ACCOUNTS FROM

Trust Fund.	Balance at 1st April, 1941. £ s. d.
Telford Fund	117 18 9
Manby Fund	9 8 0
Miller Fund	711 10 7
Howard Bequest	27 6 4
Trevithick Memorial	26 19 8
Crampton Bequest	13 18 0
James Forrest Lecture and Medal Fund	4 8 6 *Dr.*
Palmer Scholarship Fund	85 7 0
John Bayliss Bequest	43 0 9
Indian Fund	135 17 8
Vernon-Harcourt Bequest	107 3 4
Webb Bequest	328 15 9
William Lindley Fund	593 6 11
Kelvin Medal Fund	167 4 11
Charles Hawksley Bequest	89 3 2
Coopers Hill War Memorial Fund	355 9 1
C. C. Lindsay Civil Engineering Scholarship Fund	671 15 3
Baker Medal Fund	51 0 0
James Alfred Ewing Medal Fund	24 19 8
G. H. Dennison Fund	9 15 2
Totals	£3,565 11 6

RESEARC

	£ s. d.	£ s.
To Research—		
Earth-Pressures Research	1,000 0 0	
Earthing to Water-Mains Research	92 10 0	
Joint Committee on Materials and their Testing	10 0 0	
		1,102 10
To Other Expenses—		
Salaries and Pensions Premiums	186 14 8	
Less Sales of reports, etc.	24 15 10	
		161 18
		1,264 8
To Balance carried down	..	4,237 5
		£5,501 14

COMMITTEE ON THE DETERIORATION O

Account from 1st APRIL, 194

	£ s.
To Balance *carried down*	1,060 17
	£1,060 17

1ST APRIL, 1941, TO 31ST MARCH, 1942.

Income: Including Income Tax refunded for the year 1940–41.			Expenditure on Scholarships, Prizes, Lectures, etc.			Balance at 31st March, 1942.		
£	s.	d.	£	s.	d.	£	s.	d.
222	9	5	145	2	4	195	5	10
9	12	9	8	4	0	10	16	9
194	16	1	—	—	—	906	6	8
9	6	5	—	—	—	36	12	9
20	16	1	—	—	—	47	15	9
14	10	1	—	—	—	28	8	1
40	11	3	88	4	0	52	1	3 *Dr.*
54	12	4	53	15	0	86	4	4
34	0	9	15	0	0	62	1	6
42	7	8	—	—	—	178	5	4
34	9	5	—	—	—	141	12	9
46	1	9	—	—	—	374	17	6
77	13	3	110	0	0	561	0	2
29	12	11	—	—	—	196	17	10
197	1	5	—	—	—	286	4	7
53	11	6	2	5	0	406	15	7†
135	1	11	15	0	0	791	17	2
14	0	3	52	10	0	12	10	3
22	12	9	34	10	0	13	2	5
20	3	6	30	0	0	0	1	4 *Dr.*
£1,273	11	6	£554	10	4	£4,284	12	8

† Of which £214 8*s.* 2*d.* is invested (*see page 359*).

RESERVE.

	£	s.	d.
By Balance, as per last Account	3,451	14	2
„ Contribution from other Bodies	1,050	0	0
„ Institution Revenue Account—Amount provided for the year—*per page 356*	1,000	0	0
	£5,501	14	2
„ Balance *brought down as per Balance Sheet, page 352*	£4,237	5	4

STRUCTURES EXPOSED TO SEA ACTION.

TO 31ST MARCH, 1942.

	£	s.	d.
By Balance, as per last Account	1,034	6	3
„ Interest on Investment	15	16	0
„ Sales of Reports	10	15	4
	£1,060	17	7
„ Balance *brought down as per Balance Sheet, page 352*	£1,060	17	7

INSTITUTION INVESTMENTS AT 31ST MARCH, 1942 (INCLUDIN THOSE HELD IN RESPECT OF REPAIRS AND RENEWAL RESERVE) AT COST.

£	s.	d.		£	s.	d.
3,000	0	0	Metropolitan Water Board 3% "B" Stock	2,958	16	[illegible]
6,000	0	0	London and North Eastern Railway 4% Debenture Stock	7,749	18	[illegible]
6,000	0	0	London Midland and Scottish Railway 4% Debenture Stock	7,452	14	[illegible]
2,545	0	0	London Midland and Scottish Railway 4% Guaranteed Stock	1,976	7	[illegible]
5,994	15	2	3½% War Loan	3,586	11	[illegible]
2,720	5	5	London Passenger Transport Board 4½% "A" Stock .	3,327	9	[illegible]
3,809	0	2	3½% War Loan	3,824	8	[illegible]
452	0	0	London Midland and Scottish Railway 4% Guaranteed Stock	351	3	[illegible]
989	14	7	London Passenger Transport Board 4½% "A" Stock .	1,210	12	[illegible]
5,327	6	5	New Zealand 3% Stock, 1952–1955	5,334	7	[illegible]
9,400	0	0	Middlesex County Council 3% Redeemable Stock, 1961–1966	9,391	11	[illegible]
470	4	3	3% Local Loans	461	3	[illegible]
			National Gas and Oil Engine Co., Ltd., 3,336 Ordinary Shares of £1	2,668	16	[illegible]
2,000	0	0	2½% National War Bonds, 1945/47	2,000	0	[illegible]
5,000	0	0	2½% National War Bonds, 1946/48	5,000	0	[illegible]
6,000	0	0	2½% National War Bonds, 1949/51	6,000	0	[illegible]
			As per Balance Sheet, page 353 . .	£63,294	0	[illegible]

NOTE.—*The value of these Investments at ruling prices on 31st March 1942, amount approximately to* £62,364.

MADE AND PRINTED IN GREAT BRITAIN BY WILLIAM CLOWES AND SONS, LIMITED, LONDON AND BECCLES.

NOTE.—*Pages [1] to [30] can be omitted when the Journal is bound in volume form.*

NOTICES

No. 7, 1941—42

JUNE, 1942

MEETINGS, SESSION 1941—42.

ANNUAL GENERAL MEETING.

The Annual General Meeting of Corporate Members will be held on Tuesday, 23 June, at 5.30 p.m. A ballot for the election of new members will precede the meeting.

As was the case last year, it is not proposed to read the Report of the Council at the meeting, which is, instead, published beforehand in this Number of the Journal (pp. 352–362, *post*).

The Corporate Members present will be asked that the Report may be taken as read, to enable the President to review the work of The Institution during the period covered by the Report.

ROAD ENGINEERING SECTION.

June 30 (Tues.). (5.30 p.m.) Members are invited to view two films illustrating the erection of the Rainbow bridge, Niagara Falls, and the collapse of the Tacoma bridge, in the State of Washington.

GENERAL ANNOUNCEMENTS.

PUBLICATIONS.

The next Number of the Journal will be published on the 15th October.

Abstracts of Papers read at recent Meetings of the Road and Railway Engineering Sections held on the 21st and 28th April, respectively, appear on pp. [8], [9], *post*.

Pamphlet copies of the full Papers referred to, with reports of the oral discussion, may be obtained upon application to the Secretary.

PRISONERS OF WAR.

The Institution has recently been granted a permit to issue it Journal to members and students who are British or Allied Prisoners c War or Internees in Enemy or Enemy-Occupied Territory or in Neutra Countries. If relatives or friends, who have not already done so, wi intimate to the Secretary of The Institution the full addresses of suc members who would like to receive the Journal, the matter will be deal with.

REPORT ON FISH-PASSES.

HYDRODYNAMIC RESEARCH.

The attention of members is drawn to the hydrodynamic researc involved in the experimental work covered by the Report on Fish-Passe and the accompanying Appendix, which has now been published by th Institution Research Committee. An abstract of the Report appears o pp. [13]–[16], *post*.

Copies of the full Report may be purchased from Messrs. Willia Clowes & Sons, Ltd., Axtell House, Warwick Street, London, W.1, at charge of 1*s*. 6*d*. each to members and 2*s*. 6*d*. to non-members (post free

POST-WAR NATIONAL DEVELOPMENT—A CENTRAL PLANNING AUTHORITY.

The issue of copies of the Interim Report of the Post-War Nation Development Committee on matters contained in the Report of th Royal Commission on the Distribution of the Industrial Population, an particularly on the form and functions of the proposed central plannin authority (reference to which was made in the Journal for January las has been suspended pending consideration of certain information whic has recently been brought to the Committee's notice. It is anticipate that the Report will be amended with a view to meeting the poin raised, and that copies of a revised Report will be available shortly.

AERODROME ABSTRACTS.

Nos. 40–63 (Vol. 1, No. 3) of Aerodrome Abstracts are reprinted pp. [21]–[30], *post*, by permission of the Air Ministry and the Departme of Scientific and Industrial Research.

MINISTRY OF HOME SECURITY, RESEARCH AND EXPERIMENTS BRANCH.

Copies of the following additional Bulletins and of a General Stateme are now available to members, by permission of the Ministry of Ho Security, upon application to the Secretary of The Institution. Applic tion should be made by post card, quoting the Number given in the le hand column :—

Bulletin No. C.24. "Protective Walls in Single-Storey Factories. Method of Heightening and Strengthening Existing Walls."

Bulletin No. C.27. "Shelter Design."

Bulletins Nos. C.25 and 26 are *not* available for circulation to members, as they are not of interest in Great Britain.

General Statement: F.C.9 (Revised). "Application of Passive Air Defence (P.A.D.) Measures in War-Time Factories."

NOTE.—The Ministry of Home Security will be reducing the number of copies of future Bulletins, so that a small number will be available for Overseas members and the balance will only be obtainable by Home members through the services of the Loan Library of The Institution.

DEFENCE (GENERAL) REGULATIONS, 1939.

The Council wish to draw the attention of members to the new amendment to Regulation 56A of the Defence (General) Regulations, which requires the authority of certain Government Departments for the execution of building operations, the cost of which exceeds certain specified amounts. It subjects to penalties for its breach not only the persons at whose expense the work is carried out and the persons who execute it, but also "any architect, engineer or other person employed in an advisory or supervisory capacity in connexion with the execution of the operation or the carrying out of the work."

POST-WAR ENGINEERING EDUCATION.

Following the appointment of a Sub-Committee to consider questions arising in connexion with engineering education, with particular reference to post-war conditions, a memorandum on the subject has been prepared with the authority of the Sub-Committee. The memorandum is not intended to express the Sub-Committee's final views on this question, but is being issued to those known to be interested, for their comments and criticisms. Copies of the memorandum may be had on application to the Secretary.

TECHNICAL BOOKS FOR PRISONERS OF WAR.

The War Organization of the British Red Cross Society and the Order of St. John of Jerusalem has in operation a scheme for the distribution of technical books to Prisoners of War. Such books need not be new, provided that they have no marginal notes. Members who wish to give books for distribution under this scheme are invited to send, in the first place, a list of books, showing author, title, and date of publication to: Miss E. Herdman, Educational Books Section, The New Bodleian, Oxford. The lists will be scrutinized by the department, and members will then be informed which books are needed for distribution.

TRANSFERS, ELECTIONS, AND ADMISSIONS.

Since the 10th March 1942, the following elections have taken place :—

Meeting.	*Associate Members.*
14 April 1942.	17
12 May 1942.	18

and during the same period the Council have transferred 16 Associate Members to the class of full Members, and have admitted 71 Students.

DEATHS AND RESIGNATIONS.

The Council have received, with regret, intimation of the following deaths and resignations :—

Deaths.

H.R.H. Arthur, Duke of Connaught, K.G., P.C., G.B.E. (E. 1897.)	*Hon. Member.*
Carter, Dansie William. (E. 1909. T. 1927.)	*Member.*
Davies, Thomas, O.B.E. (E. 1920.)	,,
Duguid, Alexander Turner. (E. 1905. T. 1916.)	,,
Grove, Frank, O.B.E. (E. 1889. T. 1901.)	,,
Hassall, James. (E. 1907. T. 1932.)	,,
James, Charles Carkeet. (E. 1887. T. 1899.)	,,
Kirkwood, James Howie, B.Sc. (E. 1897. T. 1927.)	,,
Platt, John. (E. 1889. T. 1917.)	,,
Shadwell, Lancelot Horace Augustus, O.B.E. (E. 1904. T. 1922.)	,,
Stanford, Frederick Owen, O.B.E. (E. 1903. T. 1921.)	,,
Thompson, John Hannay, O.B.E., M.Sc., F.R.S.E. (E. 1894. T. 1906.)	,,
Bolam, Walter Norman, B.Sc. (E. 1905.)	*Associate Member.*
*Casebourne, Ralph Ward Samuel. (E. 1939.)	,, ,,
Edwards, Osborne Anthony George. (E. 1886.)	,, ,,
English, William Gordon, B.Sc. (E. 1933.)	,, ,,
*Fallows, Albert Edward, B.Sc. (E. 1939.)	,, ,,
Ferreira, Eduardo de Moraes Gomas. (E. 1884.)	,, ,,
Fielden, Edward Brocklehurst. (E. 1882.)	,, ,,
Herrod, Harold, B.Sc. (E. 1925.)	,, ,,
MacDougall, Alexander. (E. 1897.)	,, ,,
Rodwell, Frederick John. (E. 1901.)	,, ,,
Rogers, Ralph Baron, M.A. (E. 1888.)	,, ,,
*Walton, John Percy, G.M., B.Sc.Tech. (E. 1936.)	,, ,,
Waterhouse, Lawrence Maxwell. (E. 1899.)	,, ,,
*Froud, Ernest Findlay. (A. 1938.)	*Student.*
*Lowe, Geoffrey, B.Sc.Tech. (A. 1940.)	,,
*McGibbon, Hugh Parker Buchanan, B.Sc. (A. 1940.)	,,
*Rogers, Robert Edward. (A. 1940.)	,,
*Sheals, Francis Eric. (A. 1936.)	,,

* On Active Service.

Resignations.

Darling, Henry Arthur. (E. 1908.)	*Associate Member.*
Wharton, John Robert, B.A. (E. 1907.)	,, ,,

A SELECTIVE LIST OF RECENT ADDITIONS TO THE LIBRARY.

[Journals, Proceedings of Societies, etc., are not included.]

ACCIDENTS—PREVENTION. HEINRICH, H. W. "Industrial Accident Prevention." 2nd ed. 1941. McGraw-Hill. 21*s.*

ACOUSTICS. BAGENAL, H. "Practical Acoustics and Planning against Noise." 1942. Methuen. 7*s.* 6*d.*

AIRCRAFT. ANDERSON, N. H. "Aircraft Layout and Detail Design." 1941. McGraw-Hill. 21*s.*

ALLOYS. PIGOTT, E. C. "Chemical Analysis of Ferrous Alloys and Foundry Materials." 1942. Chapman & Hall. 28*s.*

AUTOMOBILES. SMITH, S. P. "Electrical Equipment of Automobiles." 4th ed. 1942. Chapman & Hall. 9*s.* 6*d.*

*BIOGRAPHY. BREARLEY, H. "Knotted String. Autobiography of a Steelmaker." 1941. Longmans, Green. 10*s.* 6*d.*

*—— MAVOR, S. "Memories of People and Places." 1940. Hodge. 10*s.* 6*d.*

*—— REDMAYNE, *Sir* R. "Men, Mines, and Memories." 1942. Eyre & Spottiswoode. 20*s.*

BOILERS. SCORER, S. D., *Ed.* "Steam Boiler Yearbook and Manual." 1942. Paul Elek. 20*s.*

BRICKWORK. MOLLOY, E., *Ed.* "Brickwork and Masonry." 1941. Newnes. 6*s.*

BUILDING CONSTRUCTION. HANSEN, E. L. "The Suitability of Stabilized Soil for Building Construction." 1941. Illinois Engineering Experiment Station, Urbana. Bull. 333. 45 cents.

—— MOLLOY, E., *Ed.* "Builders' Machinery and Equipment." 1942. Newnes. 6*s.*

CALCULATION. WILSON, S. E. "Decimal Super and Cubing Calculator." 1942. Lumberbook Co., Clevedon. 10*s.* 10*d.* post free.

CANALS. POWNALL, J. F. "The Projected Grand Contour Canal." 1942. Cotterell, Birmingham. 2*s.*

CHEMICAL ANALYSIS. *See* ALLOYS.

CONCRETE. MOLLOY, E., *Ed.* "Concrete Work." 1941. Newnes. 7*s.* 6*d.*

CULVERTS. SPANGLER, M. G. "The Structural Design of Flexible Pipe Culverts." 1941. Bulletin 153, Iowa Engineering Experiment Station, Ames, Iowa. Gratis, from Station.

DRAWING. INSTITUTION OF ENGINEERS, AUSTRALIA. "Australian Standard Engineering Drawing Practice." 1941. The Institution, Sydney, N.S.W. 6*s.*

ELECTRONICS. MILLMAN, J., and SEELY, S. "Electronics." 1941. McGraw-Hill. 35*s.*

*ENGINEERING. JONES, F. D., *Ed.* "Engineering Encyclopedia." 2 vols. 1941. Machinery Publishing Co. 48*s.*

*—— PENDRED, L. St. L., *Ed.* "Kempe's Engineer's Year Book." 1942. Morgan Bros. 35*s.*

FOUNDRY MATERIALS. *See* ALLOYS.

GAUGES. *See* MEASUREMENT.

INSTRUMENTS. RHODES, T. J. "Industrial Instruments for Measurement and Control." McGraw-Hill. 42*s.*

MASONRY. *See* BRICKWORK.

MEASUREMENT. NATIONAL PHYSICAL LABORATORY. "Notes on Gauge Making and Measuring." 1942. H.M.S.O. 2*s.*

MEASUREMENT. *See also* INSTRUMENTS.

METALLURGY. BUTTS, A. "Textbook of Metallurgical Problems." 1932. McGraw Hill. 28*s*.

—— CARPENTER, C. B. "Powder Metallurgy. A Review of its Literature. 1941. Colorado School of Mines, Golden. 3*s*.

—— SISCO, F. L. "Modern Metallurgy for Engineers." 1941. Pitman. 22*s*. 6

METAL PROCESSING. BOSTON, O. W. "Metal Processing." 1941. Chapman Hall. 30*s*.

NOMOGRAPHY. ALLCOCK, H. J., and JONES, J. R. "The Nomogram." 3rd e 1941. Pitman. 10*s*. 6*d*.

PAINTS. MATTIELLO, J. J. "Protective and Decorative Coatings. Vol. I. Ra Materials." 1941. Chapman & Hall. 36*s*.

POLAROGRAPHY. KOLTHOFF, J. M., and LINGANE, J. J. "Polarography." 194 Interscience Publishers, Inc., New York. 36*s*.

PRESS TOOLS. HOUGHTON, P. S. "Press Tool Practice, Part I." 1941. Chapma & Hall. 13*s*. 6*d*.

*PRICES. MINISTRY OF WORKS AND BUILDINGS. "Standard Schedule of Price January, 1942." 1942. H.M.S.O. 1*s*.

RAILWAYS. LEE, C. E. "The First Passenger Railway (Swansea and Mumbl Line)." 1942. Railway Publishing Co. 5*s*.

RECONSTRUCTION. HORSFIELD, H. T., and REEKIE, R. F. "Emergency Recon struction." 1941. International Voluntary Service for Peace, Leeds. No pric

ROOFS. MOLLOY, E., *Ed.* "Roof Construction and Repair." 1941. Newnes. 6

SILOS. PENNINGTON, A. M. "Concrete Farm Silos, Granaries, and Tanks." 194 Concrete Publications. 6*s*.

SOIL AND SOIL MECHANICS. MOHR, H. A. "Exploration of Soil Conditions." 2n ed. 1940. Soil Mechanics Series No. 9. Harvard University, Cambridg Mass. 7*s*. 6*d*.

*—— PURDUE UNIVERSITY. "Proceedings of the Purdue Conference on So Mechanics." 1940. The University, Lafayette, Ind. 25*s*.

"TANKS." LOW, A. M. "Tanks." 1941. Hutchinson. 9*s*. 6*d*.

TANKS. *See* SILOS.

THERMIONIC VALVES. WILLIAMS, E. "Thermionic Valve Circuits." 194 Pitman. 12*s*. 6*d*.

TOWN AND AREA PLANNING. ADSHEAD, S. D. "A New England. Planning f the Future." 1941. Muller. 7*s*. 6*d*.

—— OSBORN, F. J. "New Towns after the War." 1942. Dent. 4*s*. 6*d*.

TRAFFIC. HAMMOND, H. F., and SORENSON, L. J., *Ed.* "Traffic Engineering Han book." 1941. Institute of Traffic Engineers, New York. 21*s*.

WATER. AMERICAN WATER WORKS ASSOCIATION. "Water Quality and Treatme Manual." 1940. The Association, New York. 24*s*.

WELDING. ROSSI, B. E. "Welding and its Application." 1941. McGraw-Hi 17*s*. 6*d*.

—— TIBBENHAM, L. "Practical Handbook on Oxy-Acetylene Welding." 194 Suffolk Iron Foundry, Stowmarket. 5*s*.

WIRELESS TELEGRAPHY. DOWSETT, A. M., and WALKER, L. E. Q. "Handbook Technical Instruction for Wireless Telegraphists." 7th ed. 1942. Iliffe. 25

WORKSHOP CALCULATIONS. CHAPMAN, W. A. J. "Senior Workshop Calculations 1941. Arnold. 10*s*.

(* *The foregoing books, with the exception of those marked with an asterisk, may borrowed from the Loan Library.*)

LOCAL ASSOCIATIONS.

REPORTS.

The Paper on "Post-War Planning and Reconstruction" by Mr. H. J. B. Manzoni, C.B.E., M. Inst. C.E., was repeated at meetings of the Birmingham and District Association on the 29th April, the Bristol and District Association on the 1st May, the North-Western Association on the 25th April, and the Northern Ireland Association on the 11th May.

Birmingham and District Association.

The Annual General Meeting was held on Thursday, 14 May, and was followed by a joint meeting with the Midland Counties branch of the Institution of Structural Engineers, when Mr. T. H. P. Veal, B.Sc., Assoc. M. Inst. C.E., read a Paper on "Some Notes on Engineering Work in the Malay States."

Edinburgh and District Association.

The Annual General Meeting was held on Wednesday, 15 April, followed by a Paper on "Excavation Work" by Mr. J. L. White, B.Sc., Assoc. M. Inst. C.E.

North-Western Association.

On Saturday, 21 March, Mr. L. F. Cooling, M.Sc., read a Paper on "Soil Mechanics and Site Exploration".

South Wales and Monmouthshire Association.

The Annual General Meeting was held on Saturday, 18 April, followed by a Paper on "Concrete and the Resident Engineer", by Mr. D. F. Wilkin, B.Sc., Stud. Inst. C.E.

Southern Association.

On Saturday, 11 April, at Southampton, Mr. L. F. Cooling, M.Sc., gave a lecture on "The Study of Soils in Relation to Engineering Problems", and on Saturday, 25 April, at Southsea, a lecture on "The Analysis of Some Engineering Problems Associated with Clay Soils" was given by Mr. A. W. Skempton, M.Sc., Assoc. M. Inst. C.E.

Yorkshire Association.

On Saturday, 11 April, at Leeds, Mr. John Baker, M. Inst. C.E., read a Paper on "Shell Manufacture", and on Saturday, 9 May, at Sheffield, a Paper on "Mining Subsidence and Some Drainage Problems Arising Therefrom", by Mr. H. J. Paul, M. Inst. C.E., was discussed.

ROAD ENGINEERING SECTION MEETING.

Tuesday 21 April, 1942.

SIR FREDERICK CHARLES COOK, C.B., D.S.O., M.C.,
Chairman of the Section, in the Chair.

The following Paper was read and discussed.

Road Paper No. 5.

"The Effects of Modern Road Layout on Bridge Design."

By Cyril Stapley Chettoe, B.Sc. (Eng.), M. Inst. C.E.

(*Abstract.*) †

The Author reviews briefly the development of road layout since th last war, and considers the effects of the changes on bridge design generally and the special types of bridges and other structures which have bee necessitated by them. Two main features of modern highways ar noticeable: firstly that they are of duplicate construction; and secondl that a width of 120 feet is now common practice. If new bridges have t be designed, or old ones widened, to such a dimension it becomes difficul to make them satisfactory from an aesthetic point of view, as they loo too much like a tray on supports. Generally, therefore, consideratio should be given to the construction of (*a*) separate bridges, or (*b*) a singl bridge of duplicate construction; or there should be a longitudinal join down the middle of the centre reservation in the superstructure, an perhaps in the piers and abutments also. These alternatives are discusse in detail, with illustrative examples from British, German, Italian, an Swiss practice. Reference is made to Memorandum No. 483 of th Ministry of Transport and the layouts described therein are reviewe with consideration of the various alternative road junctions and flyov and flyunder crossings. The junctions projected for two important road in the London suburbs are illustrated. The Author also discusses th problem of pedestrian crossings by subways and footbridges. Usually pedestrian subway needs to have a headroom of at least 7 feet, and width of 7 feet 6 inches; allowing for 1 foot of construction depth, th difference of level is only 8 feet. The height to be climbed to get over footbridge is about 17 feet, so that the subway has a substantial advantag particularly where ramps are used on the approaches to accommoda perambulators. Subways are, however, often impracticable owing to th presence of underground mains and services. Two standard types

† Copies of the full Paper, with a report of the Discussion, may be obtained up application to the Secretary.

footbridge approved by the Ministry of Transport are illustrated; one has ramped approaches and the other steps. Both are designed for dual carriageways, and are of reinforced concrete. For single carriageways a steel portal design would be suitable.

The Paper is accompanied by nine sheets of drawings and nine photographs.

The following speakers participated in the discussion :—Messrs. E. J. Buckton, H. Alker Tripp, T. C. Grisenthwaite, R. G. H. Clements, J. S. Wilson, A. Kirkwood Dodds, E. R. Knight, H. E. Steinberg, and John Carr.

RAILWAY ENGINEERING SECTION MEETING.

Tuesday, 28 April, 1942.

RAYMOND CARPMAEL, O.B.E., M. Inst. C.E.
Chairman of the Section, in the Chair.

The following Paper was read and discussed.

Railway Paper No. 2.

"The Repair of War Damage to Railway Way and Works in the London Area, 1940 and 1941.

By Arthur Dean, M.Sc. (Eng.), Assoc. M. Inst. C.E.

(*Abstract.*) †

In order to meet the unknown requirements due to enemy action, the Railway Companies stored stocks of materials, tools, and plant at carefully selected sites, having alternative traffic routes and access for road transport and located close to locomotive depots. Loaded bogie bolster wagons and motor lorries were earmarked and allocated for emergency repair work. Designs were prepared of typical constructions for temporary bridging of gaps, and of typical timber trestles. Public services were located and particulars recorded. Priority of reinstatement was decided

† Copies of the full Paper, with a report of the Discussion, may be obtained upon application to the Secretary.

on and records of essential details were kept. Private direct telephone systems between railway headquarters, divisional traffic, and divisional engineers' offices were established and a motor dispatch rider service was organized. Only a few strategical centres were manned continuously, and only the most vulnerable sections of the more essential traffic routes had three or four men on duty every night, so that effective man-power should not be reduced for repair work.

As soon as was practicable after bombs had fallen inspection of the line took place, and a report was sent to the divisional traffic headquarters, who at once transmitted a report to the divisional engineer, whose responsibility it was to take the necessary emergency repair action. Arrangements were made with the War Office for the Royal Engineers (railway construction company) to supplement the labour of the railway companies, and also for the loan of standard type military steel trestles. Emergency rations for night work were stored at certain centres and repair depots and fully equipped mess and kitchen vans and mobile canteens were provided.

Valuable lessons learned from the first few raids were utilized to reorganize any arrangements found advisable, so that later, when raids were continuous, everything worked smoothly. At the end of each day arrangements were made for any available man-power that might be required the following morning, so that the divisional engineer would be free the next morning to deal with any damage done during the night. At first daylight raids interfered with repair work, but later "alerts" were disregarded.

The Author describes how temporary diversions to by-pass obstructions and damaged bridges were made, and how the damaged structures were quickly made usable. Damage to arches and tunnels was dealt with by means of steel waybeams, timber trestles, granite-dust retaining walls, pre-cast concrete slabs, and steel sheet-piling. Descriptions are given of the damage to and repair of metal bridges, abutments, and girders and also the repair of station buildings and platforms and of tidal dock walls.

The Paper is accompanied by six sheets of drawings and two photographs.

The following speakers participated in the discussion :—Messrs. W. T. Halcrow, George Ellson, V. A. M. Robertson, and W. K. Wallace ; Lieut.-Col. W. T. Everall ; and Mr. T. H. Seaton.

THE INSTITUTION OF CIVIL ENGINEERS.

THE INSTITUTION OF MECHANICAL ENGINEERS.

THE INSTITUTION OF ELECTRICAL ENGINEERS.

JOINT MEETING.

Wednesday, 15 April, 1942.

Sir NOEL ASHBRIDGE, B.Sc. (Eng.),
President of the Institution of Electrical Engineers, in the Chair.

"The Application of Statistical Control of the Quality of Materials and Manufactured Products."

Introduction by Dr. C. G. DARWIN, M.C., M.A., F.R.S.

(*Abstract.*) †

A good approach to the subject of statistical control is through consideration of the tolerances which are assigned in engineering designs. It is often not very clear how these have been chosen, and there is always a conflict between the inclinations to keep them close so as to be on the safe side and to make them easy to help the manufacturer. One of the great merits of the statistical method is that it gives reasoned instead of guessed values to the tolerances.

A simplified example is provided by the problem of making time fuses for anti-aircraft shells. The gunner tells us that the lethal region round a shell is such that if it explodes within $\frac{1}{10}$ sec. of the set time it will make a kill, and he therefore asks for a fuse accurate to $\frac{1}{10}$ sec. The manufacturer works out his method, but finds that whereas it is easy to get a fuse to $\frac{1}{5}$ sec. he will have a lot of trouble to get to $\frac{1}{10}$ sec. Indeed, he estimates that his production will be cut to a quarter if he must do so. Now half his shells will burst in the demanded range, and so the gunner, by accepting this tolerance, will get four times as many shells, of which half are effective, and so he will, in fact, double his rate of killing by accepting the larger tolerance.

There are a good many different aspects of the statistical method. Thus it may be applied to a measured quantity such as a length, or to a test of pass-or-fail type. Again, every specimen may be tested, or only

† The introductory notes and a full report of the discussion will be published in the Proceedings of the Institution of Mechanical Engineers. A limited number of pamphlet copies are available, and application should be made to the Secretary, The Institution of Civil Engineers.

a sample, as in cases where the test is destructive. To all these the statistical method applies.

In the actual case of some American time fuses the statistical method was not at first applied, and practically all the makers failed to make acceptable fuses. Major Simon of the U.S. Army, one of the most brilliant workers in this field, was called in, and introduced a method by which the tolerances achieved were at all settings a good deal finer than those asked for; and it was comparatively easy to take advantage of this in a variety of ways, for example by altering the time-setting graduations. In this way the remarkable result was achieved that fuses which repeatedly failed to pass the prescribed test were, by a trivial change, found to be more perfect than had been demanded.

The statistical theory gives a simple answer to the question of what fraction of fuses must be tested, which is an important matter since these fuses are of course all destroyed. Now that Simon's method is used it has been found necessary to test only half as many as were done before.

Introduction by Sir Frank Gill, K.C.M.G.

(*Abstract.*)

We have not the necessary knowledge to manufacture articles in large quantities and all having identical essential qualities; therefore tolerances are introduced into specifications. If a number of similar articles are taken and some quality is measured in each, we get a frequency distribution where the majority of the articles cluster round about the average measurement.

Using the data given by these measurements we can, by the probability theory, convert this figure, obtained from a relatively small number of measurements, into what it would be if a very large number were taken. A chart is prepared on which frequent measurements, for example, the product of a machine tool, can be plotted. This chart shows (*a*) the nominal dimension required, and (*b*) the plus and minus tolerance limits.

The chart shows the degree to which the desired qualities are being embodied in the product, the extent to which variation must be expected and be therefore inevitable and harmless, and the cases where the samples show harmful tendencies or actual "action points," so giving warning for instant action before the tolerance limits are reached. The main object of quality control is to improve the uniformity of the product up to the point where a "state of control" exists, that is when all, or substantially all, the plotted points lie within the two statistical control limits. When this is attained a train of benefits accrues.

Prolonged research has established so much, that a tool has been made and, as is the case with many tools, can now be used by those who know little of the design.

Factory engineers should at once begin to study the rules for the application of quality control and not by studying the statistical foundation. They should accept this foundation as already established and proceed with practical study.

A sort of primer illustrating the steps to be taken will shortly be available.

Effective, fast production is tremendously important, yet to-day production is subject to numerous unusual causes of hindrance, all of which adversely affect manufacture.

Because the effectiveness of a firm's inspection can be so well judged by the control charts, quality control should be a method which appeals to those interested in the philosophy of the Services Inspection Departments, viz. that when they are satisfied that a firm is doing a first-class inspection job, the Services will leave inspection to the firm. Just because we are at war, every method of increasing production and every technical improvement are necessary. Recent events must have made everyone realize how important is production and that everything leading to speed and accuracy is vital.

The following speakers participated in the discussion:—Dr. B. P. Dudding; Messrs. J. R. Womersley, A. R. V. Steele, G. Celioti, P. Good, H. Rissik, H. J. Lucas, and G. Watson Smyth.

REPORT OF THE COMMITTEE ON FISH-PASSES.

A sub-committee was appointed in December 1935 † to report on the subject of fish-passes, the terms of reference being:—

> To consider the desirability of carrying out investigations to determine efficient forms of fish-pass for any given water-flow and the minimum quantity necessary for any form; to prepare a scheme for the investigation and an estimate of the probable cost of the research.

The sub-committee reported in favour of the investigation, and their scheme and estimate having been approved and the financial arrangements made, the work was put in hand. The hydraulic research was completed in 1938, but for reasons beyond the sub-committee's control, the preparation of the report was delayed and, the outbreak of hostilities following, it has only now been found possible to prepare the report for publication.

† Journal Inst. C.E., vol. 3 (1935–36), p. 600 (Oct. 1936).

Abstract of Report on Fish-Passes.

Contents.

Part I.—The habit of salmon and migratory trout (sea trout) of proceeding up certain rivers to spawn, makes it essential to the preservation of the fisheries that they shall not be hindered by artificial obstructions placed in the river from reaching all their natural spawning-grounds. Until after the middle of last century the chief obstructions were mill dams and navigation weirs; in the present century the growth of hydro-electric development has led to the erection of high weirs and dams which, in the absence of suitable provision, would prove insurmountable obstacles to the fish. In most countries the fisheries are protected by legislation and the English Fisheries Acts provide for a suitable pass being constructed wherever an obstruction is built or rebuilt in a river frequented by salmon or migratory trout.

Modern passes may be divided into the following types :—

1. Pool passes with notched overflow weirs or submerged orifices.
2. Steep channel passes.
3. Fish-locks.
4. Fish-lifts or elevators.

Part II. comprises notes on the habits of fish which have a bearing on the question of fish-passes.

Part III. gives a brief survey of the special hydraulic investigations carried out for the sub-committee at the Civil Engineering Department of the Imperial College of Science and Technology by Dr. Nemenyi under the direction of Dr. White.

In both pool and channel passes, the problem is fundamentally the same, namely the dissipation of the energy of the water generated by its fall and most of the investigation was directed to various aspects of this problem.

The measure of the efficiency of a pass is ultimately the effort required by a fish to surmount it, compared to that which it can normally exert. This subject has been fully investigated both theoretically and experimentally by Mr. G. Denil, of Brussels. Experiments were carried out to check his results and were found generally to substantiate them.

On the subject of pool passes with submerged orifices, experiments were made on the dispersion of jets in closed chambers, on the effect of deflexion of the jet to obtain lateral spreading, and on upward deflexion

of the jet. The results determined the relation of the size of the pool to that of the orifice, to secure satisfactory dissipation of energy.

For pool passes with overflow weirs, an investigation was made to determine the conditions under which the jet from the overfall would give rise to surface or wavy motion, or alternatively to submerged action. The results showed that there was an abrupt transition from one motion to the other, the governing factors being the height of overfall and the up and downstream thickness of the weir; the profile of the weir had little, if any, effect.

On the subject of steep channels, the basis of the work was the investigations of Denil, who showed that by introducing an arrangement of symmetrical baffles, a continuous flow at low velocity could be maintained in a channel with a slope as steep as 1 : 4. The research was directed firstly to checking Denil's results and secondly to the design of a simpler form of baffle which would give the same action.

Part IV.—The principal factors in the selection of the type and the design of a pass are :—

Height of the obstacle.
Variation of head and tail water-levels.
Amount of water available.
Physical features of the site.

Pool passes consist of a flight of pools connected by notched overflow weirs or submerged orifices. The pool serves the double purpose of dissipating the energy and providing slack water for the fish to rest. Economy can be effected by designing the pools for the first purpose only and providing occasional larger pools in which the fish can rest. Submerged orifices have advantages over notched weirs, excepting where special difficulties occur in preventing the ingress of gravel. Pool passes can be adapted to any variations of water-level.

Steep channel passes consist of lengths of steep channel, with intermediate resting-pools. By suitable systems of baffles, a low velocity is maintained at a slope of even as great as 1 : 4. Channel passes are generally more economical than pool passes, but they have the disadvantage of being inapplicable for a greater variation of water-level than 1 foot. A special type with side baffles might, however, be used for a variation up to, say, 6 feet.

Combined pool and channel passes will provide for large variations of water-level; the pools provide for the variation and the channel for the normal height of the obstruction.

By the application of the principle of upward deflexion of the jet, a simple channel has been devised which can be used for any variation of water-level, as its characteristics are those of a narrow flight of pools. This channel shows great promise, but it requires to be tested on a full scale for the reaction of fish to it.

The fish-lock consists of a tower through which water flows, entering by an upper orifice connecting with the head water and flowing out by a lower orifice connecting with the tail water. The fish, attracted by the current, swim into the tower, but are unable to pass out through the upper orifice against the greater head. The lower orifice is then closed and the water-level in the tower rises until the velocity of inflow under the reducing head is sufficiently low for them to swim out through the upper orifice. Fish-locks are economical at high obstructions and are adaptable for any range of variation of water-level.

The fish-lift or elevator consists of a tank through which water flows and into which the fish swim, attracted by the current. The sluices are then closed and the tank is raised bodily to the upstream water-level when it is opened for the fish to pass out.

Inlet and Outlet of Pass.—The inlet to the pass, that is, the outlet for fish going upstream, requires to be designed so as to prevent the entry of gravel or debris.

The outlet or fish-entrance is of great importance as it must be readily found by the fish and must be attractive to them. The location and design require careful attention and there must be a suitable current to attract the fish. The actual flow through the pass is unimportant provided that the outflow at the fish-entrance is adequate and adjustable to the volume of flow in the river. It is economical to design the pass for a low flow and to provide a by-pass delivering a diffused flow into the entrance channel which can be adjusted to suit the stage of the river.

Fish-passes at hydro-electric stations, and the passage of smolt downstream are discussed.

The design of passes to accommodate both salmon and migratory trout, and the adaptation of passes to very low flows are considered.

Part V. Practically all existing fish-passes in this country are of the pool type, with weirs or submerged orifices.

Examples of the steep channel pass occur in Belgium, built in accordance with Denil's principles.

In this country there are no examples of either the fish-lock or the fish-lift, which has been used in America. Both are adapted to high heads, but they have the disadvantage of requiring the constant attendance of an operator when the fish are running.

The Report is published as a separate pamphlet and a detailed account of the hydraulic research is given as an Appendix thereto.

Copies can be obtained at a charge of 1*s*. 6*d*. each to members and 2*s*. 6*d*. to non-members (including postage) on application to Messrs. William Clowes & Sons, Ltd., Axtell House, Warwick Street, Regent Street, London, W.1.

INSTITUTION LUNCHEON.

A Luncheon was held by The Institution in London, on Wednesday, 6 May 1942, at which Professor C. E. Inglis, O.B.E., M.A., LL.D., F.R.S., President, was in the chair. After the toast of "The King", proposed by the President, had been loyally pledged, the Right Hon. Sir James Grigg, K.C.B., K.C.S.I., M.P., Secretary of State for War, proposed the toast of "The Institution of Civil Engineers." After personal references to some of the guests, he said that for more than a century the members of The Institution had observed a certain aloofness from their military brethren, and only recently had Royal Engineers been eligible for membership. That opening of the gate had been much appreciated; he hoped that the contacts and associations would steadily develop, certainly for the benefit of the Royal Engineers and, he hoped, also for the benefit of civil engineers.

After all, the war, with its multitude of disadvantages, had produced the advantage that the civil and military engineering professions had been set closely together once again. He had been told that more than 2,600 of the members and students were serving with the Forces, and about two-thirds of them in the Royal Engineers. The demands of modern war on military engineers had grown out of all recognition. To perform that wartime task the Corps had greatly increased, and it was still expanding. He was glad to say that in that expansion they had had the closest liaison with The Institution and every possible assistance from it.

It was, of course, not only from the absorption of its members into the Army that they had obtained help from the profession. They were being helped by eminent consultants over some of the larger constructional works, and one member was helping greatly as chairman of the Advisory Committee on army buildings. Sir James gathered that, in spite of the close contact which developed between the military and civil engineers during the last war, they did drift apart at the end of it, and the President had played a noble part in preventing the rift from becoming a definite cleavage.

The University courses which the President had conducted had been of untold advantage, and the Army could never be sufficiently grateful for what he had done in building that particular bridge. After the war was over military and civil engineers should remain in the closest contact, not only for the benefit of the community in times of peace but also in order that, should another war break out, the whole experience of both could be thrown at once into the common pool.

The President, in responding to the toast, expressed the appreciation of The Institution to Sir James Grigg for having found time amidst his many activities to be present, and for the cordial manner in which he had proposed the toast.

Sir James had referred to the alliance of The Institution with the Corp of Royal Engineers. The closer that alliance was made the better The Institution would be pleased. On its part it would do all that it could and it looked for a certain help from the military authorities in ensurin in the future—perhaps more than in the past—that all Royal Engineer should be given the opportunity of acquiring that moderate amount o practical experience which was an essential qualification for corporat membership of The Institution.

Without anticipating information which would be contained in th forthcoming Report of the Council, it might perhaps be appropriate if h referred very briefly to one or two of the Institutional activities and aspir ations. A state of war, deplorable as it was, did, at all events, provid unique opportunities for regeneration and reform, provided that difficultie were faced in a non-defeatist spirit of determination and resoluteness and that was the atmosphere in which the deliberations of the Counci were being conducted. It could be taken that the Council were very muc alive to new ideas and imbued with a deep sense of responsibility to a grades in The Institution, and for the welfare of the engineering professio as a whole.

A feature of the session which was drawing to a close had been th number of joint meetings with the Institutions of Mechanical and Electrica Engineers, and joint conferences on such subjects as the balancing o locomotives, engineering problems in connexion with air-raid protectio and statistical methods of achieving quality control, which had attracte large and variegated audiences. Co-operation between engineerin institutions, which everyone was agreed was very desirable, had made considerable advance.

The same trait had been noticeable in the educational system. Alread a joint preliminary examination was in operation, and the possibilit of a general examination, gathering all those fundamental aspects o engineering common to all branches of the profession, was unde consideration.

With the rapid evolution in all sorts of engineering development examination tests could not remain standardized or stereotyped, and the should not be embalmed in any formal code of practice. For an Institutio with its roots firmly planted there need be no fear of the consequences o raising its qualifications for entrants. That might produce a momentar kink in the curve, but the chart of admissions would soon renew its upwar trend, probably at a steeper slope than formerly, because it was only huma nature to covet that which was hardly attained, and to value but lightl privileges which could be had more or less for the asking.

The Institution had its roots very firmly planted in the ground, and i was their bounden duty to maintain a high standard of professiona qualifications, because where they led others would follow.

He hoped that in the near future The Institution would take an activ

part by providing refresher courses in subjects which came within the scope of its more general activities. Senior engineers often felt the need for such refreshment in post-graduate courses, wherein, he considered, particular prominence should be given to the subjects of industrial management and production engineering.

He would like to see a staff college set up and endowed, to which young men earmarked by their firms for responsible positions in managerial or production activity should be seconded for, say, a period of six months. Living together and exchanging ideas, they would get to know those who in days to come would be their opposite numbers in engineering and allied organizations.

The replanning and reconstruction of towns after the war was attracting the serious attention of engineers and architects. It was a field in which the two professions could be mutually helpful and could work for the common good, and he hoped that their activities in the future might be pursued together and in a spirit of amicable concord.

Sir John E. Thornycroft, K.B.E., Vice-President, in proposing the toast of " The Guests," said that science had had to solve many problems which had arisen during the war, and engineers had not been slow to provide the various things which scientists had shown to be necessary to combat new forms of warfare.

The Secretary of State for War had referred to the large numbers of engineers who had joined the Royal Engineers. That was a matter of pride to The Institution, but some felt that it would have been better if the Government—not the War Office—had in some way made use of engineering knowledge at an earlier state. Various new forms of attack which had had to be met had been solved by the scientists, and he thought that a tribute should be paid to them for the manner and speed with which they had given the answers to the problems set.

The Navy, Army, and Air Force had grown at a terrific rate, and it had been very difficult for people who had had to provide the material to meet all the demands at once. He hoped that he might be allowed to voice the appreciation felt by The Institution of the work which had been done by the administrators of all Government Departments. The President had referred particularly to the work of Sir James Grigg, but perhaps he might say a word about the work done under the aegis of the First Lord of the Admiralty. To engineers, particularly, the way in which the Navy had met successfully all those new forms of attack had earned admiration.

He coupled with the toast the name of Sir Henry Dale, President of the Royal Society.

Sir Henry H. Dale, C.B.E., M.A., M.D., D.Sc., President of the Royal Society, said that he did not need Sir John Thornycroft to tell him why he had been chosen to respond for the guests. It was because it was recognized that the Royal Society stood for British science. From its beginning it had stood for the culture of the whole tree of natural knowledge, and it

was recognized that British science, root and branch, had to-day a mor urgent duty than ever before to its own country and to the world.

Among men of science, from those who tended the growing tips of it roots in fundamental knowledge to those who, like the members of th Engineering Institutions, were busy with the farthest buds of the branche of its application, the one urgent desire was that their knowledge and thei equipment should be used to the utmost value by their country in it present need.

He had heard only one kind of complaint from workers in science, and that was that they were not yet used for the war as fully as many of them desired to be, and that expert knowledge was not always so effective a they had hoped to see it.

He hoped that the impression was dying—if it ever had existed—that men of science ought to be regarded as remote and oracular pundits fitted only to find in seclusion the answers to riddles posed by practical men. In fact, most scientific men were very practical people who, if only afforde the opportunity, could give help that was invaluable alike in finding th problems and in finding the solutions.

The war was a war of all the sciences, but particularly it was a engineers' war, and engineering and physics naturally played the most prominent parts. Victory would go to the nations which had, and knew how to use, the best services that the full range of the sciences could give We had allowed our enemies a very long start in the perversion and con scription of science to assist their purpose of dominating the world by arms He thought that we should have been prepared to back British science t win alone even against that handicap; but who could doubt, now tha British science was not alone, that victory would be won for the masse resources in research, in invention, and in technical organization of th British Empire, the United States of America, and the U.S.S.R., if the could combine them in one great machine and put it forthwith into to gear?

AERODROME ABSTRACTS.*

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Note.—The abstracts purport to be fair summaries of the original literature, but no responsibility can be accepted by the Department of Scientific and Industrial Research for the accuracy of authors' statements or for their opinions.

Publication—Alternate months. A subject- and name-index will be issued annually.

40. **Airports and National Defence**: A. B. McMullen: *Proc. 13th Nat. Asph. Conf.*, 1940, 23–9. The U.S. Civil Aeronautics Administration, in co-operation with the Army and Navy, has planned its programme of development primarily to aid national defence, while giving consideration to the improvement of civil aviation. It has been decided as a general principle that (1) no new airport will be developed within six miles, centre to centre, of any existing airport; or on, or within two miles of, the letdown legs of a radio range or instrument landing beam, if the proposed airport is within ten miles of the radio range station, and (2) airports occupied by military or naval forces may be jointly used for civil aviation by scheduled air lines if the forces are combat or tactical units but not if they are flight training units. Although many questions in aerodrome construction require further study, the engineering problems are essentially the same as those met in highway construction. All aerodromes require a dense, well-bonded wearing course to prevent permeation of rain water and deterioration of the subgrade. The danger of tyre wear and of damage caused by loose aggregate limits the permissible surface roughness. Suitable wearing courses have been obtained by using stabilized soil, bituminous macadam, sand asphalt, asphaltic concrete, oil mats and bituminous surface treatment. With certain bituminous surfacings a sand blotter seal gives a suitable surface finish. Highway experience suggests that, subject to local conditions, Portland cement

concrete, brick, block and bituminous concrete on rigid bases may b
expected to last from 22 to 30 years, low-type bituminous surfacings o
flexible bases from 12 to 15 years, and low-cost untreated surfacings suc
as water-bound macadam from 8 to 12 years. Since aircraft vary greatl
in weight and size, by which again landing speeds are determined, th
thickness of surfacing must be chosen with reference to the class of air
craft for which provision is being made or will in future have to be made
The Civil Aeronautics Administration considers that at the largest aero
dromes runways may have to be built capable of carrying in ten years
time static loads of 300,000 lb. In practice it has been found that th
impact load may be assumed to be 1½ times the static load. The widt
of runways may also depend on the use to which the aerodrome is put
Military and naval planes require 150 ft. for night operations and 200 ft
for instrument landings, and would require 300 to 600 ft. for taking o
in formation.

41. **Aerodrome Construction for the British Commonwealth Ai Training Plan** : J. A. Wilson : *Roy. Engrs' J.*, 1941, **55** (March) 68–82. The programme of aerodrome construction for the Britis Commonwealth Air Training Plan provided at the time of writing fo 124 aerodromes, of which approximately half were complete. Twenty four aerodromes were taken over from the trans-Canada transport system These fields had been laid out with two or more landing strips 500 f wide and 3,000 ft. or more long, in the form of a triangle, " <," " +, or " T " shape, the rest of the ground being cleared or rough-graded onl The fine grading and seeding of the latter and the addition of taxi strip made these fields suitable for elementary and air observers' school Building on areas adjacent to new aerodromes was restricted to 1 f vertical for every 50 ft. horizontal from the end of each landing strip fo a flightway width 600 ft. wider than the landing strip of 500 to 1,000 ft and for every 20 ft. at other points on the perimeter. *Lay-out and su facing.* For elementary schools an all-way turf surface is sufficient, bu for others hard runways are necessary. These were usually laid out t form a triangle, the interior and a 250-ft. strip outside being fine-grade and seeded. At service flying training schools, where five aircraft ma have to land abreast, landing strips are at least 1,000 ft. wide with tw hard-surfaced and three grass runways. The two relief aerodromes neede by each service flying training school have three double runways 100 f wide and 2,500 ft. long, with hard surfacing on one aerodrome. Bombi and gunnery schools, air observers' and air navigation schools have thr single runways 150 ft. wide and 2,500 ft. long. The type of constructi depends on the number and type of aircraft, nature of the soil, and aggr gate and equipment available. Base courses most commonly consisted crushed gravel, water-bound macadam or soil, gravel and bitumen ; a wearing courses of bituminous hot-mix, road-mix, or penetration surfacing

The thickness, depending on the bearing power of the soil and the type of aircraft, varies from 5 to 10 in. for the base and 1 to 2 in. for the wearing course. Drainage varies with the site, but in most cases stone-filled ditches, extending below the frost level, line all the hard surfaces on both sides. Hard surfaces have been made as impervious as possible, to prevent softening of the subgrade or frost-heave. Grasses for seeding, fertilisers and additional topsoil, where necessary, were chosen from the results of a soil and botanical survey.

42. **Meteorological and Climatic Factors in the Planning of Aerodromes** : O. WEBER : *Strasse u. Verkehr*, 1941, **27** (20), 377–83.

43. **Asphalt for Airports. Trends in the Construction of Runways and Other Airport Surfaces** : W. R. MACATEE : *Asphalt Institute : Construction Series* No. 45. New York, 1939 (The Asphalt Institute), 11 in. by 8½ in., pp. 48, fig. 35, unpriced. This publication contains the full text of a paper summarized from another source in *Road Abstr.*, 1939, **6**, No. 218. The cross-sections of thirty aerodrome runways in the U.S.A. are reproduced and details are given of the method and cost of construction. Tendencies in the design and construction of surfacings are discussed.

44. **Soil Mechanics in Road and Aerodrome Construction** : A. H. D. MARKWICK : *J. Instn. Civ. Engrs*, 1942, **18** (5), 62–87 ; Discussion (6), 155–80. The problems involving soil in road and aerodrome construction are discussed. The importance of soil classification tests is emphasized and a method of making a soil survey is described, with details of the equipment used at the ROAD RESEARCH LABORATORY for taking undisturbed samples of soil. Where paved runways are constructed both the bearing capacity of the soil and the bearing capacity of the surfacing must be considered in relation to the static and impact loads of the aircraft. The expression of the ultimate bearing capacity of the soil in terms of its mechanical properties is dealt with by H. L. D. PUGH and the Author in an Appendix. A second Appendix considers the application of dimensional analysis to the bearing capacity of soil under aeroplane tyres. On the basis thus obtained conclusions are drawn as to the stability of cohesive and granular soils and the pressure exerted on the ground in relation to size of tyre and type of soil. Pressures in and beneath runways are considered for rigid surfacings, such as concrete, and flexible surfacings, such as tar macadam on pitched foundations and sand asphalt. A single arterial drainage system is usually employed to deal with storm-water and subsoil water. The water-table should be maintained well below the surface and subsoil drains should be placed at or below the water-table level. Recommended depths and spacing of subsoil drains for various soils are given. (Abstractor's Note :—The road aspects of this paper are dealt with in *Road Abstr.*, 1942, 9, No. 249.)

45. **Wheel Load Stress Distribution through Flexible Type Pavements** : M. G. Spangler and H. O. Ustrud : *Proc. Highw. Res. Bd. Wash.*, 1940, **20**, 235–57. (See *Road Abstr.*, 1942, **9**, No. 218.)

46. **Building Bases for our Air Forces** : Anon. : *Engng News-Rec.*, 1940, **125** (17), 544–55. This review describes the principles of design and construction adopted for a number of naval and military aerodromes in the U. S. A. Full descriptions are given of grading operations, drainage systems, and various types of runway surfacings. (See *Road Abstr.*, 1942, **9**, No. 178.)

47. **Principles of Design of Airport Drainage** : Anon. : *Publ. Wks, N.Y.*, 1941, **72** (4), 39–43. The purpose of an aerodrome drainage system is (1) to control underground water, (2) to remove storm water, and (3) to keep the surface moderately dry. It is subject to heavier wheel and impact loads than other types of drainage, and does not permit of open ditches or gutters. Experience has shown that one system of drains is usually sufficient for all three purposes, since storm water is quickly removed. A main network of pipes will carry off storm water, and laterals joining this will remove underground water. Under these principles, particular systems will be designed with regard to the following conditions :—(1) type of traffic, (2) possibility of expansion, (3) description of site, including type of soil and level of water-table, and (4) weather conditions. *Storm drainage.* Usually a storm with a frequency of at least once in 10 years will be chosen as the " design " storm, but the possible effects of worse storms will be considered. If all the water is to be removed within two hours from the cessation of the storm, the system will usually be running at maximum capacity within 45 min. of the beginning. It has been calculated by O. C. Carter that for the drainage system at the Columbus municipal airport (see following Abstract) 40 min. was a representative time, the area at the time of study being 170 acres. Run-off from paved areas is 85 to 100 per cent of the rainfall, and from sodded areas 10 to 25 per cent. The main drains should be placed along each side of the runways, along edges of taxi strips and aprons and in the lowest areas between runways, so that surface flow is short. Storm water may be collected by means of channels parallel to the edges of paved areas or by storm water inlets or by both. A common method is to lay drainage pipe in a trench backfilled with porous material or covered by a continuous grating. *Subsurface drainage.* The amount of water flowing into the subsoil is small, and the main function of subdrainage is to ensure a stable subgrade in all weathers. If it is required only to lower the water-table, the depth of collector pipe can be less than if it is also required to eliminate capillary saturation. The U.S. War Department (see Abstract No. 11) has given approximate figures for the depth and spacing of sub-drains in different types of soil, the spacing ranging from 150 to

300 ft. in sand to 25 to 30 ft. in clay. Drains are not usually required under runways. To ensure good drainage in periods of intermittent freezing and thawing, trenches should be filled with porous material except for the top 6 in. which should be similar to the more pervious surface material to prevent clogging by the entry of fines. Such a drain will function as soon as the thaw has penetrated to 6 in. All clay pipe should be of A.S.T.M. standard. The article is illustrated by examples taken from various aerodromes.

48. **Port Columbus Drainage System Serves Well** : Anon. : *Publ. Wks, N.Y.*, 1941, **72** (4), 13–4. The drainage system of the Columbus municipal airport, built in 1929, has proved very satisfactory. The site, consisting of a 12-in. layer of fairly heavy black soil underlaid with yellow clay, has a slope towards the south-west of 2 to 3 ft./1,000 ft. *Storm drainage.* A deep creek near the north-east corner was used as an outlet. The drains were placed on the downslope side of the runways, allowing for extension. The main drain, 48 in. in size, having a slope of 1 in 1,000 and capacity of 50 cu. ft./sec., serves an area of about 350 acres. It consists of reinforced concrete culvert pipe, which has about twice the area of reinforcement of an ordinary reinforced concrete pipe. Other drains of A.S.T.M. vitrified sewer pipe were arranged to have a capacity of 1 cu. ft./sec. for every 150 linear feet of runway. *Sub-drainage.* Of nine borings 42 in. deep, all showed a heavy clay likely to drain slowly, except for two where fine shaly material was present. Two 5-in. drains were placed longitudinally under the 100-ft. runways; within 200 ft. of the runways drainage lines were placed at intervals of 30 ft. and elsewhere at intervals of 60 ft. Those next to the runways, and every fourth drain elsewhere, are gravel-filled, the top 8 in. being crushed limestone graded 2 to 3 in. in size. Their capacity is 1 cu. ft./sec. for each 200 linear feet on the downslope next to the runway, 1 cu. ft./sec. for every 700 linear feet along the 30-ft. taxiway, and 1 cu. ft./sec. for every 15 acres elsewhere. Other drains have gravel backfill around and for 6 in. above the pipe, earthfill elsewhere and a capacity of about 1 cu. ft./sec. for every 30 acres. The minimum size of pipe used is 5 in., and the minimum cover 2 ft. The 8-in., 10-in., and 12-in. sizes are of extra thick and strong drain tile, and the others of A.S.T.M. vitrified shale drain tile.

49. **Electrical Drainage of Fine Soils** : L. Casagrande : *Strasse*, 1941, **8** (19/20), 324–6. To overcome the difficulty encountered in excavating fine-grained soils such as clay, loess, or silt, whose high capillarity may render the usual methods of drainage ineffective, large-scale experiments with an electro-osmotic process have been carried out by the German State Railway Directorate (*Reichsbahndirektion*) at Hanover. The process consists in inducing osmosis in the soil by passing an electric

current through a series of electrodes, thereby causing the water in fin grained soils to move from one electrode to another. (A fuller summar is given in *Road Abstr.*, 1942, **9**, No. 216.)

50. **Army Builds an Arctic Airbase** : ANON. : *Engng News-Rec* 1940, **125** (17), 558–9. The construction of a U.S. Army airbase at Lad Field, near Fairbanks, Alaska, presented great difficulties owing to con ditions of perpetual frost in the subsoil and the distance of the site fro supplies and labour. The site was a plain of 1,000 acres and the soi sand and silt over gravel, provided good foundations. The dense timb covering the site was rooted in muskeg, an 18-in. layer of moss over th silt, which formed a blanket under which the ground was perpetuall frozen. By removing the muskeg blanket the summer warmth wa enabled to penetrate and thaw the ground surface. After hand clearin the moss was stripped by 16-cu. yd. tractor-hauled carrying scraper Explosives were used for excavating the frozen ground. Two intersectin concrete runways 150 ft. wide and 1 mile long are provided for. Con struction of the first occupied three weeks in the late summer of 194 The second was to be built by the following spring. The concrete wa laid in 20-ft. strips, with a dummy joint every 20 ft. and a moulded expan sion joint every 60 ft. ; the subgrade was prepared by placing an 18-in layer of gravel, tile-drained. Slab concreting was done with steel form with a paver travelling in the subgrade alongside, and a finished machin with oscillating screed and belt, moving on the forms.

51. **Fort Wayne's New Airport** : F. L. SPANGLER : *Rds and Str* 1941, **84** (10), 48, 50, 52, 54, 58. The Fort Wayne, Indiana, municip airport has two intersecting runways each 300 ft. wide consisting of 100-ft. concrete centre strip with an 88-ft. strip of soil-cement on eac side and 12 ft. of concrete forming a shallow gutter and inclined ke along each outside edge. Near the north end of the area, between th two runways, is a concrete apron with five taxi strips connecting the ru ways. At the south end a 150-ft. soil-cement runway connects the en of the two main runways. The amount of concrete and soil-cement wo involved is equivalent to 39 miles of 25-ft. surfacing. The excavati work amounted to 1,300,000 cu. yd. ; the topsoil was stripped to a average depth of 9 in. from all areas to be paved and, after stripping, th runway locations were scarified and broken by disc harrows to a depth 4 in. A high-density frostproof sub-base was produced by removing si pockets and filling in with layers of a mixture of sand, clay, and sil Proctor tests were made to determine optimum moisture for each of th various soils encountered and the moisture content was held to withi 2 per cent. of this optimum on all compacted material. Embankme material was spread in layers not more than 6 in. deep. Where th

moisture content was too great, the layer was cultivated with 24-in. disc harrows, operated in a tandem offset arrangement, until tests showed the desired moisture condition. The layer was then rolled with sheepsfoot rollers pulled by track tractors. Each roller unit consisted of four rollers weighing 7,858 lb. each, and from 10 to 30 passes were required. In the cuts, the subgrade for both concrete and soil-cement surfacings was prepared by discing the clay to a depth of 3 in. and then mixing it with sand or sandy gravel, employing sufficient water to produce a friable consistence and ensure uniform incorporation of the granular material with the clay. After the resulting layer was mixed, it was brought to the optimum moisture content and compacted to the required density by sheepsfoot rollers, bladed and smoothed with a patrol grader during the rolling operation, and then rolled with a smoothfaced self-propelled tandem roller. The drainage system included 45,385 ft. of 12-in. to 48-in. concrete pipe. Run-off on the unpaved areas is collected by 10,450 ft. of French drains with perforated galvanized pipe from 8 in. to 21 in. in diameter, and by 14 concrete ground inlets connected by corrugated pipe to storm sewer manholes. Gullies 150 ft. apart drain the run-off from runways, aprons, and taxi strips. The reinforced concrete surfacing slabs are of 8–6–8 in. section. The soil-cement strips are 7 in. thick. The proportion of cement was 7½ per cent. of the dry weight of aggregate, which consisted of 25 per cent. top soil or strippings and 75 per cent. of a well-graded sand-gravel mixture from a nearby pit. Construction was by the road-mix method. The aggregate was placed on the subgrade between forms 20 ft. apart and spread with cement. After being mixed by disc and harrowing units, the materials were brought to optimum moisture content by sprinkling, and compacted by sheepsfoot rollers. The surface was shaped by graders and finished with a smooth roller. The soil-cement slab was cured for 7 days under a wet straw covering. A ¼-in. seal coat of rapid-curing cut-back bitumen and limestone chippings was applied to all soil-cement surfaces. (Abstractor's Note :—An anonymous article dealing with the soil-cement construction on this aerodrome has appeared in *Engng News-Rec.*, 1942, **128** (1), 38–40.)

52. **Soil-cement Construction Speeds Army Airfield Projects :** Anon. : *Constr. Meth.*, 1941, **23** (9), 46–7, 106, 108. Performance data are given for mixed-in-place cement-stabilized soil construction on U.S. Army aerodromes. At one U.S. Flying School Airport three contractors' outfits together averaged more than 13,000 sq. yd. of 6-in. surfacing per working day, a maximum of 16,200 sq. yd. being reached. Total soil-cement construction at this field was approximately 260,000 sq. yd. Both runway areas and apron were built in alternate strips 25 ft. wide, using 6-in. by 6-in. timber forms. The proportion of cement used was 9 per cent. by volume. Curing was done under damp earth. Construction operations and equipment are illustrated.

53. **Soil-cement Runway for Army Air Base placed with Enrichment in Top Inch** : ANON. : *Engng News-Rec.*, 1941, **126** (15), 531–3 (See *Road Abstr.*, 1941, **8**, No. 345.)

54. **Airplane Plant Runways Built in Eight Working Days** : C. H. McLAUGHLIN : *Soil-Cement News*, 1942, No. 6, pp. 1, 4. An assembly plant aerodrome comprising 102,300 sq. yd. of runways and taxi strips was constructed of low-cost soil-cement in the equivalent of eight 24-hour working days. Before construction was begun, soil samples were submitted for laboratory analysis and a 10 per cent. Portland cement mix was found suitable. The depth of the soil-cement surfacing was 6 in., and the moisture-density control factors were found to be a dry weight of 112 lb./cu. ft. and a moisture content of 13·5 per cent. ; 25,000 cu. ft. of bank-run gravel from borrow pits opened on the field was placed and processed on the runways. Details of labour and plant used are given. Much of the equipment was brought to the job by farmers and operated by them. A maximum construction rate of 700 sq. yd. per hour was attained.

55. **Tests show Soil-cement Unhurt by High-test Gasoline** : ANON : *Soil-Cement News*, 1942, No. 6, p. 1. Tests made by the U.S. PORTLAND CEMENT ASSOCIATION on stabilized specimens of sandy loam containing 8 per cent. cement by volume and clay containing 12 per cent. cement by volume showed that high-octane aviation spirit is not detrimental to soil-cement surfacings.

56. **Stabilization of Gravel Runways on Washington National Airport** : H. AARON and J. A. KELLEY : *Publ. Rds, Wash.*, 1941, **22** (8), 167–82, 191–2. Author's summary. The Washington National Airport was built under the joint supervision of several Federal agencies. This report covers the participation of the U.S. PUBLIC ROADS ADMINISTRATION in the stabilization of the gravel runways. The runways, varying in length from 4,200 to 6,875 ft. and surfaced with 3½ in. of bituminous concrete on a stabilized gravel base 9 in. thick, are located almost entirely on what was originally shoal water and mud flats along the Virginia shore of the Potomac River. This low area was filled to an elevation of 12 to 16 ft. above the normal water level with material consisting of sand, gravel, cobbles, silt, and muck pumped by means of hydraulic dredges from borrow pits located in the river on the outskirts of the field. By placing the pipelines of the hydraulic dredges longitudinally along the runways, the granular material was collected in the runway areas and the silt and muck floated off to be deposited by ponding in the intermediate areas between and outside the runways. The gravel in the runways was combined with soil from adjacent upland areas to produce a dense, well-graded, stable base course for the bituminous concrete surfacing. The

work of stabilization consisted of scarifying the graded gravel runways, removing oversize stone, adding the proper amount of soil, mixing the gravel and soil by means of cultivators, disc harrows, and ploughs, compacting with rollers, and shaping with motor graders and drags. The desired gradings, physical properties, and densities were obtained by co-ordinating the construction operations with laboratory tests performed on the materials and the mixtures. (Abstractor's Note :—Space does not permit of a more informative summary of this lengthy, detailed, and fully illustrated paper. See also, Abstracts Nos. 15, 16, and 38.)

57. **Review and Comparison of the Most Important Machines and Apparatus used in Soil Stabilization** : J. HUMMELSBERGER : *Teer u. Bitum.*, 1941, **39** (23/24), 227–32. (See *Road Abstr.*, 1942, **9**, No. 238.)

58. **Army Lays a Portable Runway at an Airfield** : ANON. : *Engng News-Rec.*, 1941, **127** (18), 625. A brief illustrated note describes the experimental use of perforated interlocking steel surfacing plates as a temporary runway surfacing on sandy soil at Marston, North Carolina. The plates, which weighed about 150 lb., were placed by hand after the runway site had been levelled by dragging. The experimental runway was 3,000 ft. long and 300 ft. wide.

59. **Destruction of Weeds on Landing Areas** : SCHOENE : *Flughafen*, 1941, **9** (4), 1–3.

60. **Prevention of Damage to Flying Fields by Pests** : G. KAVEN : *Flughafen*, 1941, **9** (6), 1–5. The use of calcium cyanamide is strongly recommended since it discourages both weeds and a number of insect pests. To combat other pests such as moles and rats special suggestions are made.

61. **The Destruction of Field-mice** : G. KAVEN : *Flughafen*, 1941, **9** (8), 13–6. Considerable damage, examples of which are illustrated, may be done by field-mice to airfields on loam or sandy loam. Methods are described of exterminating them by putting down poison gas or solid poison.

62. **Aerodrome Runway Surfacings from the Point of View of Lighting** : W. ZUERL : *Strassenbau*, 1941, **32** (4), 55–8. A discussion of the light-reflecting properties under artificial illumination of various types of runway surfacing in both the dry and wet state.

63. **Highway, Street and Airport Snow Removal and Ice Control** : ANON. : *Publ. Wks, N.Y.*, 1941, **72** (10), 32, 34–8, 43–4. In the course of a longer summary of the article, that appears in *Road Abstr.*, 1942, **9**,

No. 237, it is mentioned that the equipment required for removing snow from aerodromes depends upon the depth of snow expected. High banks at the margins of runways are dangerous to aircraft, and the most effective clearing units are one-way and rotary ploughs. In light snow the one-way plough works outwards from the centre to the margins of the runway. Heavy snow can be treated either by a rotary plough or by a reversible-blade plough for subsequent removal. The use of snow fences, natural or artificial, is recommended to prevent or minimize the formation of drifts.